KUR-World

Water Quality

Chapter 9.0

Environmental Impact Statement

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9.0 WATER QUALITY

The purpose of this Chapter is to:

- Describe the existing regulatory frameworks regarding the assessment of the project on water quality
- Provide the findings of the survey work undertaken on the site
- Identify the impacts of the project on water quality
- Identify current regulatory management tools
- Provide mitigation and management measures to support those regulatory tools which will be applicable throughout the life of the project.

There is commonality of purpose and approach to the management of water quality across the jurisdictional boundaries associated with World Heritage Areas that are relevant to the project. The site is located near the Wet Tropics of Queensland World Heritage Area, the Great Barrier Reef World Heritage Area, the Wet Tropics of Queensland National Heritage Place and the Great Barrier Reef National Heritage Place. These environmental values are Matters of National Environmental Significance (MNES). A detailed account of water quality for the project is presented in the following with consideration of MNES presented in Chapter 19.

9.1 Executive Summary

Field and desk-based assessments were undertaken by NRA Environmental Consultants (NRA) to ascertain the potential and actual water quality matters relevant to the KUR-World project area. The results of NRA's assessments inform this chapter of the EIS, the NRA report is included in Appendix 6.

The project area is located in the Barron River catchment, with three local sub-catchments recognised within the project area (Owen Creek, Warril Creek and Cain Creek). All creeks discharge to the Barron River approximately 1 kilometre north of the project area. The Barron River ultimately discharges to the Great Barrier Reef Marine Park, approximately 25 kilometres downstream of the site.

Queensland waterways are managed under the Queensland *Environmental Protection (Water) Policy* 2009 (EPP (Water)), which groups watercourses into river basins for water quality management activities. The *Barron River Basin Environmental Values and Water Quality Objectives* report (EHP 2014a) lists the environmental values (EVs) applicable to surface waters within the Barron River Basin. Surface water EVs have been assigned to the Barron River Basin according to sub-catchments. Corresponding water quality objectives (WQOs) protect the assigned EVs. For the protection of aquatic ecosystem EVs, the condition of, or level of protection required for, waters in each sub-catchment is also considered and scheduled under the EPP (Water). Sites waters are mapped as moderately disturbed (MD).

MD WQOs (based on default values scheduled in the EPP (Water) are not being achieved under baseline conditions in the waters of the project area, and the receiving environment has no further assimilative capacity for some water quality indicators. The most important existing impacts on surface water quality is accelerated soil erosion and an increased load of total suspended solids and associated turbidity, metals and nutrients. Historic or existing land-use practices upstream and on the project site have contributed to impacts on water quality, which is preventing the achievement of nominated WQOs for waters within and downstream of the project area. This has important implications for the proposed management of discharges to receiving waters and has been considered in the planning of the project and the development of mitigation measures.

The management intent for MD waters as defined in the EPP (Water) is that the decision to release waste water or contaminants into a waterway must ensure the measures of physical or chemical indicators are progressively improved to achieve the nominated WQOs. Achieving a WQO means that the corresponding EV (and associated use) will be protected. Therefore, management of point and diffuse sources from the KUR-World development should ensure that receiving water quality progressively improves and that the project design and operation should aim to have a net positive impact on water quality.

The potential impacts to surface water and groundwater from the KUR-World development include spills of hazardous chemicals, land clearing, stormwater and waste water; these are expected to be mitigated through appropriate on-site management of hazards (for example through a Hazardous Substances Management Plan and Environmental Management System, consistent with SDS 2017), with spills contained and cleaned up. Potential impacts to the receiving environment will be mitigated by the capture and treatment of site waters through stormwater management Water Sensitivity Urban Design (WSUD) and a waste water treatment system. An Erosion and Sediment Control Plan (ESCP) will be developed for construction and operation to minimise erosion and sediment loss. Nutrient loads from the Waste Water Treatment Plant (WWTP) discharge will be offset by improving water quality through mitigation measures in the catchment that receives discharge, and rehabilitation plans for improving frog habitat are expected to have a positive impact on water quality. Where on-site treatment alone is unlikely to allow direct discharge and achievement of the management intent as defined in the EPP (Water), additional mitigation measures have been proposed.

9.2 Statutory framework

There is Commonwealth and State legislation regarding water quality that is potentially relevant to the project. The relevant legislation is discussed in detail in the KUR-World Water Quality and Aquatic Ecology Technical Report (Appendix 6, refer to Section 2.1). The legislation identified is presented below:
State legislation related to issues of water quality and aquatic ecology includes:

- *Water Act 2000*
- Water Plan (Barron) 2002
- *Environmental Protection Act 1994*
- *Environmental Protection (Water) Policy 2009 (EPP (Water))*
- *Fisheries Act 1994*.

Relevant policies and guidelines include:

- State Planning Policy (SPP) July 2017, State interest – Water quality.
- Environmental Protection (Water) Policy 2009 - Barron River Basin, Environmental Values and Water Quality Objectives - Basin No 110 and Adjacent Coastal Waters (EHP 2014a).
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).
- Monitoring and Sampling Manual – Environmental Protection (Water) Policy 2009 (EHP 2013a).
- Queensland Water Quality Guidelines 2009 (EHP 2013b).
- Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines (Simpson et al. 2013).
- Wet Tropics Water Quality Improvement Plan 2015-2050, Version 10 (Terrain NRM 2015).
- Reef Water Quality Protection Plan 2013 (State of Queensland 2013).

Commonwealth legislation and policy related to water quality and aquatic ecosystems are:

- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).
- Reef 2050 Long-term Sustainability Plan (Commonwealth of Australia 2015).

9.3 Surveys

To inform the study the following baseline monitoring programs have been undertaken on and around the project area:

- surface water
- stream sediment
- aquatic ecology – aquatic macroinvertebrates
- aquatic ecology – fish
- groundwater.

Monitoring was undertaken between 5 December 2016 and 19 June 2017. The specific details of the work undertaken are presented in KUR-World Water Quality and Aquatic Ecology Technical Report (Appendix 6, refer to Section 3).

9.4 Findings

9.4.1 Existing Hydrology

9.4.1.1 Surface water hydrology

The topography of the project area (refer to Chapter 3) includes distinct ridgelines separated by deeply incised, steep-sided creek channels as shown on Figure 3-9 (see Chapter 3) and Figure 9-1 below. The elevation across the project site ranges from approximately 300 metres to 500 metres. There is a gradient in elevation across the project area, with the highest elevations (490-509 metres) occurring in the south-east (Mount Haren) and south-west corners, grading towards the lowest points in the north of the site. Creeks follow the general landscape gradient and flow towards the north of the site.

The project area is located in the Barron River catchment (Figure 9-2). The site is located approximately 2 kilometres from the Wet Tropics of Queensland World Heritage Area the Wet Tropics of Queensland National Heritage Place, and approximately 8.5 kilometres from the Great Barrier Reef World Heritage Area and the Great Barrier Reef National Heritage Place. These environmental values are Matters of National Environmental Significance (MNES). Three local sub-catchments are recognised within the project area (Owen Creek, Warril Creek and Cain Creek). All creeks discharge to the Barron River approximately 1 kilometre north of the project area. The Barron River ultimately discharges to the Great Barrier Reef Marine Park, approximately 25 kilometres downstream of the site. The watercourse determinations within these catchments under the Queensland *Water Act 2000* are presented in Figure 9-2. Descriptions of each sub-catchment are provided separately below.

Details on water levels, discharges and freshwater flows measured at different flow conditions are provided in the Surface Water Hydrology Technical Note (NRA 2017d[1]).

[1] NRA (2017d) is included as Appendix 7

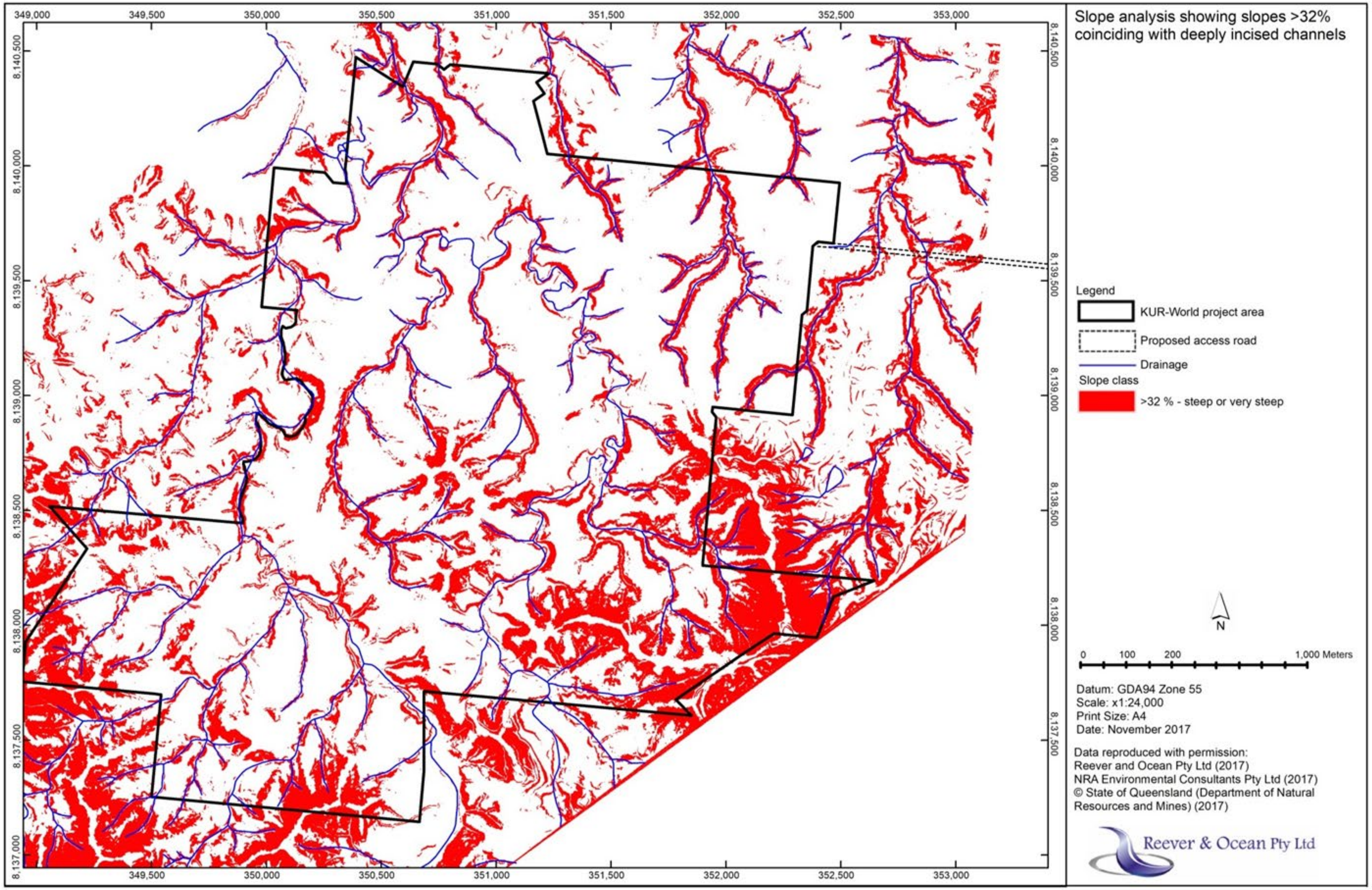


Figure 9-1 Slope analysis showing slopes >32% coinciding with deeply incised channels.

9.4.1.1.1 Owen Creek

The Owen Creek sub-catchment dominates the site (approximately 1,625 hectares overall), occupying approximately three quarters of the project area. This includes a major tributary, Haren Creek, which occupies the central section of the project area. Owen Creek is located along the western boundary of the project area. Owen Creek and Haren Creek are predominantly rocky creeks with a number of closely spaced, moderately to deeply incised tributaries in a convergent tributary channel pattern. The deeply incised channels are more prominent in the areas with generally lower relief through the central and northern parts of the site where the majority of the development will occur.

Owen Creek becomes a third order stream when it meets Haren Creek (that is, both Haren and Owen Creeks are second order streams upstream of their confluence). The Owen Creek sub-catchment flows north and joins the Barron River approximately 900 metres from the northern boundary of the project area. Both Owen and Haren Creeks were observed to flow all year in 2016, although flow in both was reduced to a near trickle in the mid-dry season.

9.4.1.1.2 Warril Creek

The Warril Creek sub-catchment occupies the majority of the remaining quarter of the project area (the sub-catchment is approximately 505 hectares overall). Warril Creek, a second order stream for most of its length, is east of the eastern boundary of the project area.

A first order tributary of Warril Creek flows through the far north-eastern corner of the project area. Within the project area, this first order tributary is predominately a deeply incised sandy creek with a number of closely spaced drainage lines/gullies forming a convergent tributary channel pattern. It did not hold water in the 2016 dry season and was only observed to flow after the first wet season storms. It converges with the main Warril Creek channel approximately 2 kilometres after leaving the northern project area boundary.

9.4.1.1.3 Cain Creek

Cain Creek is a first order stream. The upper Cain Creek sub-catchment is located in the centre of the project area northern boundary. Its total sub-catchment area is approximately 80 hectares, and it flows directly into the Barron River 850 metres after leaving the project area. It is a deeply incised, sandy creek and has substrate and channel characteristics similar to the Warril Creek tributary to the east. It crosses Barnwell Road near the northern project area boundary and was observed to run at this point all year in 2016 (albeit with very low flow in the late dry season).

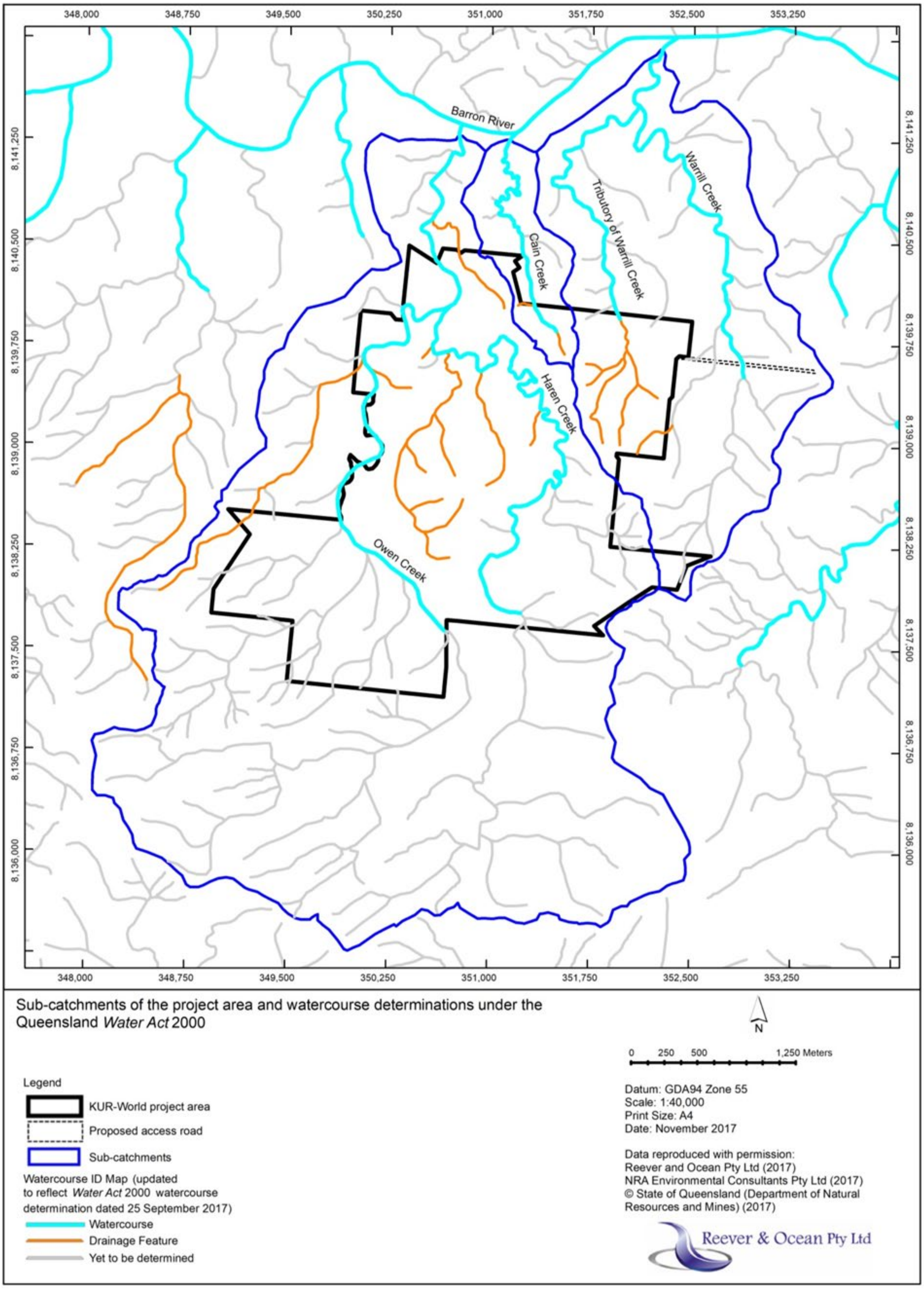


Figure 9-2 Sub-catchments of the project area and watercourse determinations under the Queensland *Water Act 2000.*

9.4.1.1.4 Observations of bed characteristics and sediment load

The main soil types on-site (described in Appendix 1, Soils and Geology) have a high proportion of fine particles (silt and clay) in the soil profile. Surface soils are relatively stable, but subsoils may be a source of fine sediment when disturbed. The majority of sub-catchments on-site (and along the route of proposed site access from the Kennedy Highway) contribute fine sediment to the system, although the sediment load varies with sub-catchment characteristics such as slope and disturbance. The exception to this is the drainage lines in the south-western portion of the site, which comprise the upper reaches of Owen Creek and exhibit little to no evidence of fine sediment transport. This area is dominated by *Corymbia clarksoniana* and *Eucalyptus tereticornis* woodland, largely on areas mapped as a mixture of Galmara and shallow Seymour soils on steep slopes that are likely to have a higher proportion of coarse fragments than soils lower in the landscape, as shown on Figure 3-9 and Figure 3-10 (see Chapter 3).

9.4.1.2 Groundwater hydrogeology

The groundwater hydrogeology of the project area was described and assessed in the KUR-World Groundwater Report (RLA 2017) and is summarised below.

The project area is located mainly over a geological formation known as the Barron River Metamorphics, which is a lithological correlative of the Hodgkinson Formation (see Chapter 3, Site Description).

9.4.1.2.1 Surficial sediments – an aquitard

Overlying the Barron River Metamorphics is a 5 to 10 metres thick layer of very weathered metasediments and clayey hillwash sediments that have either developed in place or are the product of mass wasting from more elevated areas. For the purposes of this groundwater assessment, these are known as surficial sediments. The surficial sediments are generally clayey and rarely sandy, but they act as a confining layer for the main aquifer located immediately below them. In general, the surficial sediments are only saturated during, and immediately following, the wet season. They are not regarded as an aquifer (refer to geological cross section in Chapter 3, Figure 3-6).

9.4.1.2.2 Barron River and Metamorphics – the prime aquifer

Based on information from the Department of Natural Resources and Mines (DNRM) groundwater database, the main aquifer in the KUR-World vicinity comprises fractured rock within the Barron River Metamorphics. Groundwater resides in the void spaces and fractures along these bedding planes, which are sub-vertical and trend in a north-west to south-east direction.

Aquifers within the Barron River Metamorphics are recharged primarily by direct vertical infiltration of rainfall. It is estimated that 5% to 10% of rainfall received in the area percolates to the water table. The rest of the rainfall evaporates, runs off or is stored in the soil as soil water. The water table of the project area has the potential to vary seasonally by up to 2.5 metres. Vertical movement of water to the water table is generally slow. There is a lag time of two to three months between significant rainfall and the corresponding peak in the water table. Recharge only occurs once the surficial sediments are fully saturated. This means that virtually no recharge occurs in the first few spring storm events where most of the rainfall received runs off. Little to no recharge occurs during the long, relatively dry period from May to November. Very little flushing of the aquifer by recharging water occurs in the prime aquifer sequence as rainfall recharge is generally a slow process, which likely accounts for the observations of saline or mineralised water in some neighbouring bores.

9.4.1.2.3 Mareeba Granite – hydrogeological basement

The Barron River Metamorphics have been intruded by the Mareeba Granite, which has contact metamorphosed the original sedimentary sequence. Intrusion of the granite was accompanied by emplacement of quartz veins, which generally traverse to the bedding trend of the Barron River

Metamorphics. As the magma cooled, the quartz veins contracted and shattered. These quartz veins provide lateral continuity between groundwaters residing in the saturated bedding planes of the Barron River Metamorphics.

The Mareeba Granite outcrops to the south of the project area. It is hydrogeologically unproductive in the Kuranda area owing to its massive nature, and it is regarded as the hydrogeological basement for the project area.

9.4.1.2.4 Hydrogeology

Groundwater is the component of rainfall that passes through the soil into the underlying saturated zone. Groundwater flow is primarily from east to west in the project area at a gradient of 1.25%.

The water table has been estimated to be at least 5 metres below the creek levels, even at the lowest topographic point (near SW03, Figure 9-3). Over much of the site, the water table is approximately 10 metres below creek levels. Given these observations and taking into account a potential rise of 2.5 metres in the water table following the wet season, it is not possible for groundwater to discharge into the creeks. Therefore, it is concluded that no groundwater – surface water exchange is possible in the project area. It is possible that water moves laterally through surface sediments and discharges into creeks providing some base flow during the dry season, but this has not been established.

9.4.1.3 Chemical and physical characteristics of surface water and groundwater

9.4.1.3.1 Surface water environmental values and water quality objectives

Queensland waterways are managed under the Queensland *Environmental Protection (Water) Policy 2009* (EPP (Water)), which groups watercourses into river basins for water quality management activities. The *Barron River Basin Environmental Values and Water Quality Objectives* report (EHP 2014a) lists the environmental values (EVs) applicable to surface waters within the Barron River Basin (Table 9-1). Surface water EVs have been assigned to the Barron River Basin according to sub-catchments. Corresponding water quality objectives (WQOs) protect the assigned EVs. For the protection of aquatic ecosystem EVs, the condition of, or level of protection required for, waters in each sub-catchment is also considered (that is high ecological value (HEV) waters, slightly disturbed (SD) waters, moderately disturbed (MD) waters and highly disturbed (HD) waters) and scheduled under the EPP (Water). The EPP (Water) defines the management intent for waters of different conditions. Achieving a WQO means that the corresponding EV (and associated use) will be protected.

Waterways of the project area are part of 'Kauri, Groves, Thirty Three Mile, Blackwater, One Mile, Mona, Jumrum, Haren and Dismal Creeks' sub-catchment[2] and are mapped as MD waters. MD waters are defined as waters in which the biological integrity of the water is adversely affected by human activity to a relatively small but measurable degree. Sections of Haren Creek and Owen Creek upstream of the project are mapped as HEV waters. HEV waters are defined as waters in which the biological integrity is effectively unmodified or highly valued. These HEV waters coincide with the Formartine Forest Reserve south-west of the project area and Barron Gorge Forest Reserve south-east of the project area, and these HEV waters will not be affected by the development.

Due to the proximity of the project area to the Barron River, a second sub-catchment, the 'Barron River main channel between weir at Koah and Barron Falls' is also relevant. All waters within the 'Barron River main channel between weir at Koah and Barron Falls' sub-catchment are mapped as MD waters.
Surface water WQOs for base and high flow conditions are presented in Table 9-2 and were used to assess the baseline water quality conditions of the project area.

[2] This sub-catchment also includes Cain Creek, Owen Creek and Warril Creek.

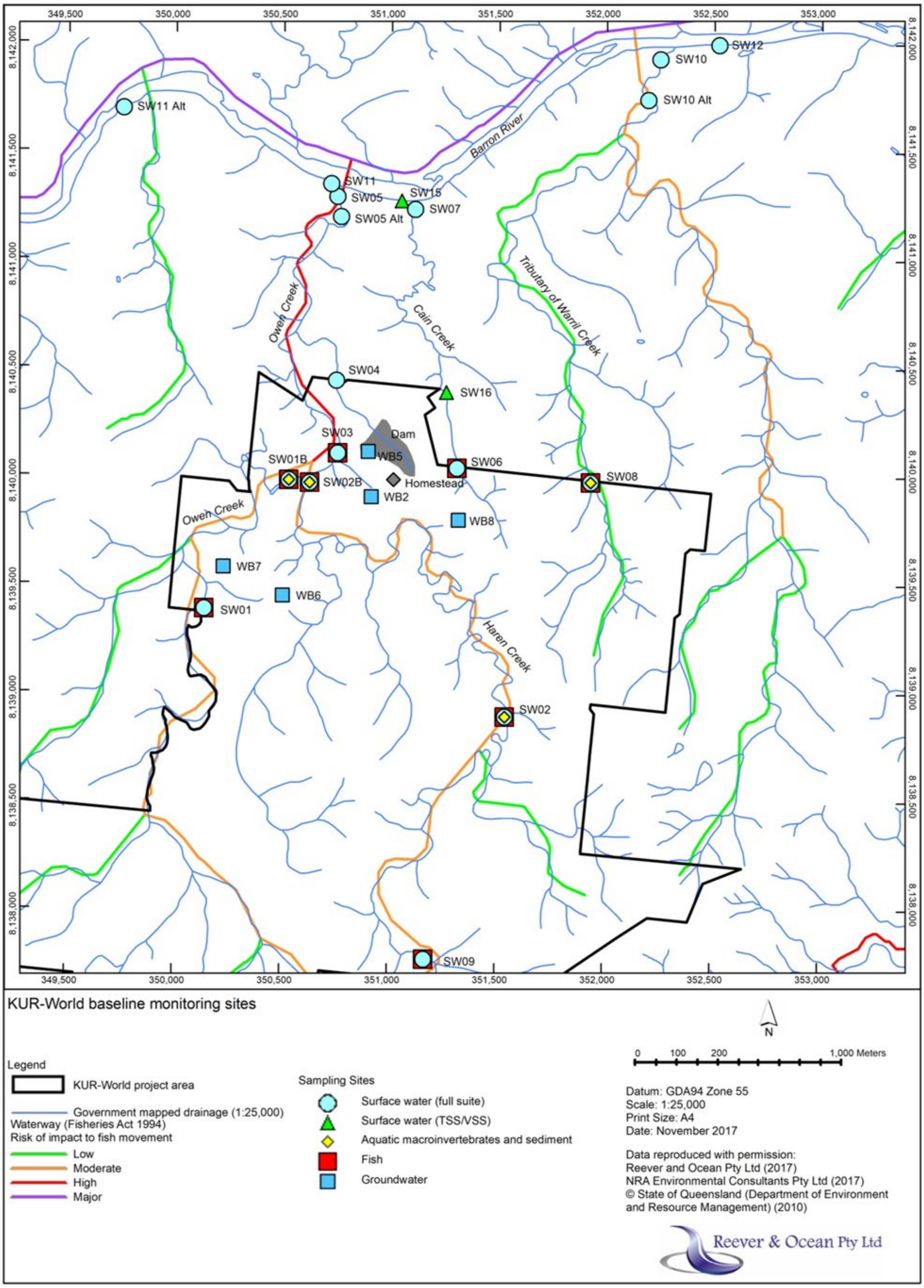


Figure 9-3 KUR-World baseline monitoring sites.

Table 9-1 Environmental values for the KUR-World project area receiving waters (EHP 2014a).

Barron River Basin sub-catchments	Aquatic ecosystems (MD)	Irrigation	Farm supply/use	Stock water	Aquaculture	Human consumption	Primary recreation	Secondary recreation	Visual appreciation	Drinking water	Industrial use	Cultural and spiritual
Kauri, Groves, Thirty Three Mile, Blackwater, One Mile, Mona, Jumrum, Haren and Dismal Creeks	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
Barron River main channel between weir at Koah and Barron Falls*	✓	×	×	×	×	✓	✓	✓	✓	×	✓	✓

*This sub-catchment is outside of the project area but downstream of project activities.

Table 9-2 Surface water quality objectives for environmental values relevant to the KUR-World project area under base flow and high flow conditions.

Analyte	Units	Project-specific WQO (Base Flow)[1,2]	Project-specific WQO (High Flow)[1,2]
pH	pH units	6.5-8.0	-
Dissolved oxygen	% saturation	85-120	-
Electrical conductivity	µS/cm	106	-
Temperature	°C	16-34	-
Turbidity	NTU	15	-
Total suspended solids	mg/L	8	52
Total dissolved solids	mg/L	-a	-
Total oxidised nitrogen	mg/L	0.05	0.101
Ammonia as nitrogen	mg/L	0.01	0.013
Total nitrogen	mg/L	0.34	0.668
Filterable reactive phosphorous	mg/L	0.008	0.004
Total phosphorous	mg/L	0.025	0.05
Dissolved aluminium	mg/L	0.055	-
Total aluminium	mg/L	0.2	-
Dissolved arsenic	mg/L	0.01b	-
Total arsenic	mg/L	0.01	-
Dissolved cadmium	mg/L	0.0002	-
Total cadmium	mg/L	0.002	-
Dissolved chromium	mg/L	0.001	-
Total chromium	mg/L	0.05	-

Analyte	Units	Project-specific WQO (Base Flow)[1,2]	Project-specific WQO (High Flow)[1,2]
Dissolved copper	mg/L	0.03	-
Total copper	mg/L	0.2	-
Dissolved iron	mg/L	0.20	-
Total iron	mg/L	0.2	-
Dissolved lead	mg/L	0.0034	-
Total lead	mg/L	0.01	-
Dissolved manganese	mg/L	0.01	-
Total manganese	mg/L	0.1	-
Dissolved nickel	mg/L	0.011	-
Total nickel	mg/L	0.02	-
Dissolved zinc	mg/L	0.02	-
Total zinc	mg/L	2	-
Sodium	mg/L	11	-
Fluoride	mg/L	0.11	-
Potassium	mg/L	TBC	-
Calcium	mg/L	1000	-
Chloride	mg/L	14	-
Sulfate	mg/L	2	-
Hardness (as CaCO3)	mg/L	60-350	-
Total alkalinity (as CaCO3)	mg/L	33	-

Source: See Appendix 6.

TBC – Site-specific guideline value to be calculated.

[1] The WQOs presented here apply to the sub-catchments of the project area and not the waters of the Barron River downstream of the project area. Different EVs, and therefore potentially different WQOs, apply to the Barron River main channel.

[2] While there is a WQO for magnesium presented in EHP (2014a) for the aquatic ecosystem EV, it is known that magnesium ameliorates the toxicity of many metals (Markich and others 2002); therefore, exceedances of the regional specific WQO for magnesium do not represent a decline in water quality. Accordingly, no WQOs for aquatic ecosystem protection were adopted for magnesium. As there is no default ANZECC and ARMCANZ (2000) guideline value and no WQOs for other EVs for magnesium, a WQO has not been presented here. Monitoring data for magnesium will be used for interpretive purposes only.

[a] As total dissolved solids is analogous to electrical conductivity, a WQO has not been provided for both indicators. Refer to the WQO for electrical conductivity.

[b] The WQOs for aquatic ecosystems are based on dissolved arsenic. These concentrations are greater than the Australian Drinking Water Guideline Value for arsenic based on total arsenic. To protect all EVs, dissolved arsenic has been set at the same concentration as the total concentration for the protection of all relevant EVs.

9.4.1.4 Surface water quality

The surface water quality of the project area was measured and assessed in the KUR-World Water Quality and Aquatic Ecology Technical Report (Appendix 6) and is summarised below.

The concentrations or values of a number of surface water quality indicators exceeded WQOs under base flow conditions (Table 9-3). This included physico-chemical properties, nutrients (forms of nitrogen and phosphorus), metals and metalloids, major and minor ions and alkalinity analytes. Exceedances of WQOs were recorded at monitoring sites adjacent to and downstream of the project area, at background or benchmark sites upstream of the proposed development in the project area, and in the Barron River, upstream of where waters from the project area enter the Barron River. In general, the WQOs that were not achieved were similar across all waters monitored.

WQOs for high flow conditions have been developed for several indicators, including total suspended solids, total oxidised nitrogen, ammonia, total nitrogen, filterable reactive phosphorus and total phosphorus (Appendix 6). Water quality at background and benchmark sites during at least one of the high flow sampling events exceeded the high flow WQOs for ammonia, total nitrogen and total phosphorus. High flow WQOs for all analytes (total suspended solids, forms of nitrogen, forms of phosphorus) were exceeded at several sites adjacent to and downstream of the project area on at least one of the high flow sampling events (Table 9-3).

Table 9-3 Summary of exceedance of Default WQOs in surface waters during baseline monitoring.

Creek and site	Location relative to project area	Surface water indicators exceeding WQO under low flow conditions and not accounted for by benchmark/background levels or modified by hardness[1]	Surface water indicators exceeding WQO under high flow conditions and not accounted for by background concentrations or modified by hardness
Haren Creek			
SW09	Upstream (Background)	19 of 44 WQOs not met during 5 sample events. pH (1/5), dissolved oxygen (DO) (5/5), electrical conductivity (EC) (5/5), turbidity (2/5), total suspended solids (TSS) (3/5), ammonia (4/5), total nitrogen (TN) (5/5), total phosphorus (TP) (3/5), dissolved aluminium (4/5), total aluminium (3/5), dissolved iron (5/5), total iron (5/5), dissolved manganese (4/5), total manganese (5/5), total sodium (4/5), total hardness (5/5), chloride (4/5), sulfate (1/5), total alkalinity1/5).	2 of 6 WQOs not met during 2 high flow sample events. Ammonia (2/2), TN (2/2).
SW02	Within	19 of 44 WQOs not met during 5 sample events, with the following WQO exceedances outside benchmark/background levels during the same sample event. pH (4/5), DO (3/5), EC (1/5), turbidity (1/5), TSS (1/5), ammonia (3/5), TN (1/5), TP (1/5), dissolved iron (4/5), total iron (5/5), dissolved manganese (4/5), total manganese (2/5), total hardness (3/5), sulfate (1/5).	1 of 6 WQOs not met during 2 high flow sample events, with the following WQO exceedances outside benchmark/background levels during the same sample event. Ammonia (1/2).
SW02B	Within	11 of 44 WQOs not met during 1 sample event, with the following WQO exceedances outside benchmark/background levels during the same sample event. TON, TN, dissolved aluminium, dissolved iron.	No monitoring undertaken at SW02B during high flow conditions.
Owen Creek			
SW01	Upstream (Benchmark)	16 of 44 WQOs not met during 5 sample events. pH (4/5), DO (5/5), EC (4/5), ammonia (4/5), TN (5/5), TP (4/5), dissolved aluminium (2/5), total aluminium (2/5), dissolved iron (5/5), total iron (5/5), dissolved manganese (4/5), total manganese (2/5), total sodium (4/5), total hardness (5/5), chloride (5/5), total alkalinity (1/5).	1 of 6 WQOs not met during 2 high flow sample events. Ammonia (1/2).
SW01B	Within	12 of 44 WQOs not met during 1 sample event. pH, DO, EC, ammonia, TN, dissolved and total iron, dissolved and total manganese, total sodium, total hardness, chloride.	No monitoring undertaken at SW01B during high flow conditions.

Creek and site	Location relative to project area	Surface water indicators exceeding WQO under low flow conditions and not accounted for by benchmark/background levels or modified by hardness[1]	Surface water indicators exceeding WQO under high flow conditions and not accounted for by background concentrations or modified by hardness
SW03	Within	20 of 44 WQOs not met during 5 sample events, with the following WQO exceedances outside benchmark/background levels during the same sample event. pH (1/5), DO (1/5), TSS (1/5), TON (3/5), ammonia (4/5), TN (3/5), TP (3/5), dissolved iron (5/5), total iron (2/5), dissolved manganese (4/5), total manganese (2/5), total hardness (2/5).	4 of 6 WQOs not met during 2 high flow sample events, with the following WQO exceedances outside benchmark/background levels during the same sample event. TSS (1/2), ammonia (2/2), TN (2/2), TP (2/2).
SW05 and SW05 Alt	Downstream	18 of 43 WQOs not met during 3 sample events, with the following WQO exceedances outside benchmark/background. pH (1/3), DO (1/3), TON (3/3), ammonia (1/3), TN (1/3), TP (1/3), dissolved iron (2/3), dissolved manganese (3/3), total hardness (1/3).	5 of 6 WQOs not met during 1 high flow sample event, with the following WQO exceedances outside benchmark/background levels during the same sample event. TON, ammonia, TN, filterable reactive phosphorus (FRP), TP.
Tributary of Owen Creek			
SW04	Downstream	12 of 43 WQOs not met during 1 sample event, with the following WQO exceedances outside benchmark/background levels. Turbidity, TSS, TN, FRP, TP, dissolved and total aluminium, dissolved chromium, dissolved iron, total hardness, sulfate.	4 of 6 WQOs not met during 1 high flow sample event, with the following WQO exceedances outside benchmark/background levels. TSS, TN, FRP, TP.
Cain Creek			
SW06	Downstream	15 of 44 WQOs not met during 5 sample events, with the following WQO exceedances outside benchmark/background levels. pH (3/5), turbidity (1/5), TON (5/5), TN (1/5), TP (1/5), total aluminium (1/5), dissolved chromium (1/5), total hardness (5/5).	4 of 6 WQOs not met during 2 high flow sample events, with the following WQO exceedances outside benchmark/background levels. TON (2/2), TN (1/2), TP (1/2).
SW07	Downstream	13 of 43 WQOs not met during 2 sample events, with the following WQO exceedances outside benchmark/background levels. pH (1/2), TON (2/2), total iron (1/2).	No monitoring undertaken at SW07 during high flow conditions.
Warril Creek			

Creek and site	Location relative to project area	Surface water indicators exceeding WQO under low flow conditions and not accounted for by benchmark/background levels or modified by hardness[1]	Surface water indicators exceeding WQO under high flow conditions and not accounted for by background concentrations or modified by hardness
SW08	Downstream	16 of 44 WQOs not met during 4 sample events, with the following WQO exceedances outside benchmark/background levels. pH (3/4), TON (4/4), total iron (1/4), total hardness (3/4), sulfate (1/4).	3 of 6 WQOs not met during 2 high flow sample events, with the following WQO exceedances outside benchmark/background levels. TON (1/2).
SW10 and SW10 Alt	Downstream	17 of 43 WQOs not met during 4 sample events, with the following WQO exceedances outside benchmark/background levels. pH (1/4), TON (4/4), TN (2/4), TP (1/4), dissolved iron (1/4), total iron (1/4), total hardness (2/4).	4 of 6 WQOs not met during 2 high flow sample events, with the following WQO exceedances outside benchmark/background levels. TON (2/2), TN (2/2), TP (1/2).
Barron River			
SW11 and SW11 Alt	Upstream	18 of 43 WQOs not met during 4 sample events, with the following WQO exceedances outside benchmark/background levels. Turbidity (1/4), TSS (1/4), TON (3/4), TN (2/4), FRP (1/4), TP (1/4), dissolved aluminium (2/4), total aluminium (2/4), total hardness (1/4).	6 of 6 WQOs not met during 2 high flow sample events, with the following WQO exceedances outside benchmark/background levels. TSS (1/2), TON (2/2), TN (2/2), FRP (1/2), TP (1/2).
SW12	Downstream	21 of 43 WQOs not met during 4 sample events, with the following WQO exceedances outside benchmark/background levels and upstream levels during the same sample event. pH (1/4), turbidity (1/4), TON (1/4), TN (1/4), dissolved aluminium (1/4), hardness (1/4).	6 of 6 WQOs not met during 2 high flow sample events, with the following WQO exceedances outside benchmark/background levels and upstream levels during the same sample event. TON (1/2), TN (1/2).

[1] 44 WQOs were used for this comparison. Only 43 WQOs were available for some sites as fluoride was added to the monitoring suite during the last sample event (20-21 April 2017) and not all sites were sampled during this event.

Baseline monitoring identified that a number of surface water quality indicators exceeded local WQOs for the EVs of the sub-catchments in the project area. This means that under baseline conditions, waterways potentially impacted by point or diffuse discharges from the project do not achieve designated WQOs and that the corresponding EVs (largely aquatic ecosystems EV in MD condition) are not currently protected. This means that, for some water quality indicators, the assimilative capacity of water to receive inputs has been exceeded. According to the EPP (Water), it is the management intent for the MD waters that the decision to release waste water or contaminants (into a waterway) must ensure the measures of physical or chemical indicators are progressively improved to achieve the WQOs. Therefore, management of point and diffuse sources should ensure that receiving water quality progressively improves and that the project design and operation should aim to have a net positive impact on water quality. As MD WQOs (based on default values scheduled in the EPP (Water)) are not being achieved under baseline conditions, it is crucial to develop site-specific WQOs (based on water quality at baseline and benchmark sites upstream of the project area) that provide realistic targets against which to compare achievement of the management intent. Because the waters are affected by a range of land holders, it may not be possible for the project to manage discharges to the extent that WQOs are achieved downstream of the site, but the project should not prevent it from being possible.

Existing water quality reflects both historic and current land use within, and upstream of, the project area as follows:

- Historic aerial photography shows that large parts of the project area, including the majority of the northern portion of the project area, were largely or partially cleared of woody vegetation between the 1940s and the early 1990s. Land clearing would have resulted in impacts to receiving creeks by increasing sediment loads and the concentration of associated nutrients and metals in waters and by leading to sediment smothering of creek beds, impacting on aquatic ecosystem habitat quality. Impacts would have been greatest at the time of clearing, with the establishment of grass and pasture cover, or regrowth vegetation, reducing the level of impact.
- In 2014, approximately 46 hectares of this regrowth vegetation was cleared to reinstate pasture (Appendix 5, Flora and Fauna technical report), which is likely to have increased impacts on adjacent and downstream water quality until exposed soil surfaces were stabilised by grass and pasture cover in these areas.
- Historic and continuing disturbance related to operations upstream of the project area include a paintball course encompassing the bed and banks of Haren Creek and an operating quarry and creek crossings and tracks (Owen Creek catchment).
- Cattle grazing occurs within the project area. While most paddocks are fenced, cattle have access to the banks and beds of waterways and have the potential to increase the volume of suspended sediments and associated contaminants (including nutrients and metals) entering creeks through the disturbance of creek beds and banks. These disturbances degrade water quality, increase sediment deposition and decrease the quality of the instream aquatic habitat.
- Historic and current on-site activities also include general surface disturbance associated with tracks and infrastructure. Land disturbance for tracks and infrastructure increases the mobilisation of sediments and degrades water quality and aquatic ecosystem habitat. Prior to the 2016 wet season, the site access road was realigned and the tracks and crossing were upgraded; this included erosion and sediment controls such as the installation of rock surfaces at crossings and approaches and installation of sediment traps.
- New infrastructure constructed in 2015 and 2016 including a terraced organic produce garden and on-site farm dam.
- Damage to creek banks caused by feral pigs.

- The existing farm homestead is connected to a septic tank system. The condition of the septic system and potential influence (for example nutrient inputs) on surface water is unknown.

The most important existing impact on water quality is due to accelerated soil erosion and an increased load of total suspended solids and associated turbidity, metals and nutrients. Historic or existing land-use practices upstream of, and on, the project site have contributed to impacts on water quality that are preventing the achievement of nominated WQOs for waters within and downstream of the project area. This has important implications for the proposed management of discharges to receiving waters and has been considered in the planning of the project and the development of mitigation measures.

9.4.1.5 Groundwater environmental values and water quality objectives

The *Barron River Basin Environmental Values and Water Quality Objectives* report (EHP 2014a) lists the environmental values applicable to groundwaters within the Barron River Basin. Groundwater environmental values are applied at the basin level. Where groundwaters are in good condition, the intent is to maintain the existing water quality (EHP 2014a).

Water Quality Objectives (WQOs) for groundwaters of the project area were developed based on the environmental values as detailed in Table 9-4. Groundwater WQOs are presented in Table 9-5 and were used to assess the baseline water quality conditions of the project area.

Table 9-4 Environmental values for the KUR-World project area groundwaters (EHP 2014a).

Barron River Basin	Aquatic ecosystems	Irrigation	Farm supply/use	Stock water	Aquaculture	Human consumption	Primary recreation	Secondary recreation	Visual appreciation	Drinking water	Industrial use	Cultural and spiritual
Groundwater	✓	✓	✓	✓	×	×	×	×	×	✓	✓	✓

Table 9-5 Groundwater WQOs for environmental values relevant to the KUR-World project area.

Analyte	Units	Project-specific WQO
pH	pH units	6.5-7.9
Electrical conductivity	µS/cm	90-570
Total dissolved solids	mg/L	-[a]
Total oxidised nitrogen	mg/L	TBC
Nitrate as nitrogen	mg/L	1.58
Ammonia as nitrogen	mg/L	0.01
Total nitrogen	mg/L	0.34
Filterable reactive phosphorous	mg/L	0.008
Total phosphorous	mg/L	0.025
Dissolved aluminium	mg/L	0.055
Total aluminium	mg/L	0.2

Analyte	Units	Project-specific WQO
Dissolved arsenic	mg/L	0.01[b]
Total arsenic	mg/L	0.01
Dissolved cadmium	mg/L	0.0002
Total cadmium	mg/L	0.002
Dissolved chromium	mg/L	0.001
Total chromium	mg/L	0.05
Dissolved copper	mg/L	0.01
Total copper	mg/L	0.2
Dissolved iron	mg/L	0.02
Total iron	mg/L	0.2
Dissolved lead	mg/L	0.0034
Total lead	mg/L	0.01
Dissolved manganese	mg/L	0.03
Total manganese	mg/L	0.1
Dissolved nickel	mg/L	0.011
Total nickel	mg/L	0.02
Dissolved zinc	mg/L	0.01
Total zinc	mg/L	2
Sodium	mg/L	97
Fluoride	mg/L	0.50
Potassium	mg/L	-
Magnesium	mg/L	13
Calcium	mg/L	25
Chloride	mg/L	61
Sulfate	mg/L	6
Hardness (as CaCO3)	mg/L	60-115
Total alkalinity (as CaCO3)	mg/L	151

Source: Appendix 6.

TBC – Site-specific guideline value to be calculated.

[a] As total dissolved solids is analogous to electrical conductivity, a WQO has not been provided for both indicators. Refer to the WQO for electrical conductivity.

[b] The WQO derived for dissolved arsenic was based on the WQO for aquatic ecosystem EVs, whereas the WQO for total arsenic was based on drinking water. As the WQO for total arsenic is more conservative than the WQO for dissolved arsenic, the total metals WQO has been applied for both total and dissolved arsenic.

9.4.1.6 Groundwater quality

Groundwater quality of the project area was described and assessed in Appendix 6 (Water Quality technical report). The groundwater of the project area is variable between bores and did not meet WQOs for a number of water quality analytes. In general, groundwater of the project area is characterised by acidic water, elevated nutrients (forms of nitrogen and phosphorus) and metals and metalloids (including aluminium, arsenic, copper, iron, lead, manganese and zinc) when compared to WQOs. As groundwater WQOs (based on default values scheduled in the EPP (Water)) are not being achieved under baseline conditions, it is crucial to develop site-specific WQOs (based on water quality at baseline and benchmark sites up gradient of the project area) that provide realistic targets against which to compare achievement of the management intent.

Although some of the groundwater WQOs are based on protection of aquatic ecosystems at a basin-wide level, the KUR-World Groundwater Report (RLA 2017) did not identify groundwater-surface water interaction in the project area.

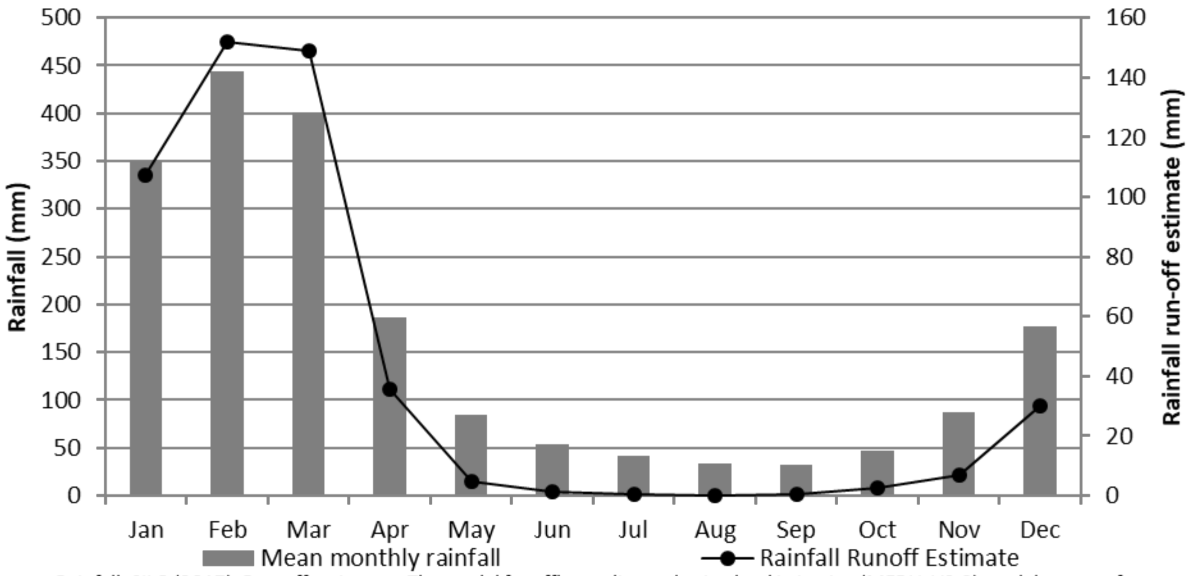
Existing impacts within the project area include changes in land use and the influence of tree clearing on rainfall interception and leaching of nutrients. Grazing areas are likely to increase nutrient leaching if coupled with fertiliser additions.

Groundwater quality may also have been affected by long-term influences from off-site land uses including land clearing and residential development, septic and other sewage transport and storage systems and agricultural land uses (including application of fertiliser and pesticides) that occur in the Myola and Kuranda areas.

9.4.2 Climatic and seasonal factors affecting water quality

The KUR-World project is located in the wet tropics of far north Queensland and experiences pronounced wet and dry seasons. The wet season is nominally from November to April. The average rainfall and potential to generate run-off is significantly higher during the months of January to March than the early and late wet season months (Figure 9-4). Average rainfall and the potential to generate run-off is lower during the dry season months.

This seasonal rainfall pattern has a major influence on surface water flow conditions and surface water quality in the project area. High rainfall and associated creek flows generate increased sediment, nutrient and metals loads that are reflected in seasonal differences in surface water quality. These seasonal influences on water quality were observed during the baseline monitoring surveys undertaken during 2016-2017, as described in Appendix 6 and below. Existing land disturbance and land uses upstream of and on the project site can be a source of sediment that is mobilised during high rainfall events. This is deposited in creek beds and may impact on instream habitat quality where it changes the nature of the sediments found in place.



Source: Rainfall: SILO (2017); Run-off estimates: The model for effluent disposal using land irrigation (MEDLI V2.0) model outputs for Bicton soil type (which is the most hydraulically limiting at the site).

Figure 9-4 Average rainfall and estimated run-off for the KUR-World Project.

Prior to the onset of the wet season turbidity values and the concentrations of total suspended solids, nutrients and total and dissolved aluminium were the lowest recorded at some sites. In contrast, electrical conductivity values and the concentrations of major ions, minor ions and bicarbonate alkalinity were the highest recorded at some sites.

These patterns in the surface water data are not unexpected. Rainfall increases the discharge of suspended sediments into, or the remobilisation of sediments within, the creeks. This leads to increases in water quality indicators associated with sediments, including nutrients and metals. Rainfall and run-off also dilute the levels of other water quality indicators, including electrical conductivity.

As expected, after the wet season, surface water was characterised by increasing levels of electrical conductivity, ions and alkalinity. This may be the result of concentration as water evaporates and creeks dry, or due to inputs from infiltrated water flowing through surficial sediments into the creek systems. The influence of water from surficial sediments has not been confirmed.

Aquifers within the Barron River Metamorphics are recharged primarily by direct vertical infiltration of rainfall, with an estimated 5% to 10% of rainfall received percolating to the water table. The water table of the project area has the potential to vary seasonally by up to 2.5 metres. Recharge only occurs once the surficial sediments are fully saturated, meaning that virtually no recharge occurs in the first few wet-season storm events where most of the rainfall received runs off. Little to no recharge occurs during the long, relatively dry period from May to November. Very little flushing of the aquifer by recharging water occurs in the prime aquifer sequence as rainfall recharge is generally a slow process, which likely accounts for the observations of saline or mineralised water in some neighbouring bores.

Climate change modelling indicates an increase in the frequency and severity of extreme weather conditions in the wet tropics, including floods, droughts and destructive storms (WTMA 2008). Additional storm generated flow may result in longer periods with poorer water quality or a greater number of pulses of poorer water quality compared to dry season conditions.

9.5 Potential discharges of water and contaminants and its impacts

9.5.1 Proposed action and its impacts

The KUR-World development is proposed to include the following components:

Stage 1A:

- Farm Theme Park and Equestrian Centre (Phase 1)
- Residential Precinct: Queenslander Lots (21 lots)
- Organic Produce Garden
- Services and Infrastructure (Phase 1)
- Environmental Area (Phase 1).

Stage 1B:

- Farm Theme Park and Equestrian Centre (Phase 2)
- Residential Precinct: Lifestyle Villas (56 lots)
- Open Space
- KUR-Village (Phase 1)
- Four Star Business and Leisure Hotel and Function Centre (Phase 1, 60 suites)
- Residential Precinct: Premium Villas (39 lots)
- Rainforest Education Centre and Adventure Park
- Services and Infrastructure (including a sewerage treatment plant, access road from Haren Road to Rainforest Education Centre) (Phase 2)
- Environmental Area (Phase 2).

Stage 2:

- KUR-Village (Phase 2)
- Four Star Business and Leisure Hotel and Function Centre (Phase 2, 210 suites)
- Sporting Precinct
- Golf Club House and Function Centre
- Golf Course
- Residential Precinct: Premium Villas (154 lots and 60 units)
- Services and Infrastructure (Phase 3)
- Environmental Area (Phase 3).

Stage 3:

- Health and Wellbeing Retreat (60 suites)
- Residential Precinct: Premium Villas (93 lots)
- Five-Star Eco-Resort (200 rooms)
- KUR-World Campus
- Services and Infrastructure (Phase 4)
- Environmental Area (Phase 4).

The project has the potential to result in a range of direct and indirect impacts to surface water, groundwater, stream sediment and aquatic ecosystem values. The potential project-related impacts are described below.

9.5.1.1 Potential impacts

The proposed construction of the project will require land disturbance and some clearing of vegetation. The potential impacts are summarised as follows.

- Land clearing and site disturbance (during construction and operation) increases the risk of erosion and sediment run-off, which increases sediment, nutrient and metal loads in creeks and changes aquatic ecosystem habitat and conditions.
- The establishment of roads and increased vehicle access to the project area increases the risk of contaminated stormwater entering creeks. Associated contaminants may include hydrocarbons and metals.
- The operation of a Waste Water Treatment Plant (WWTP) and associated irrigation and discharge of treated waste water, can impact on surface water and groundwater quality. This impact can occur through the infiltration of water with elevated nutrient and microbiological contaminants and irrigation run-off, or through the direct discharge of increased suspended solids, nutrient loads and microbiological contaminants to creeks.
- The on-site storage of hazardous chemicals increases the risk of spills leading to contamination of stormwater, project area creeks and groundwater (refer to Section 4.6 of the KUR-World Project Hazards, Health & Safety Assessment (SDS 2017)).
- Irrigation of the Golf Course/gardens may lead to increased leaching and/or run-off of fertilisers, nutrients and sediments, which can alter water quality chemistry in the receiving groundwater and surface water systems and change local aquatic ecosystem conditions.
- Dust from exposed surfaces exacerbated by vehicle and machinery movements may carry contaminants that may enter creeks, impacting on water quality and instream habitat.
- Maintenance of animal enclosures/stables may result in contamination of run-off and wash-down water (particularly nutrients and biochemical oxygen demand (affecting dissolved oxygen)).
- Operation of the produce garden may result in increased concentrations of sediment and nutrients in run-off water.
- Abstraction of groundwater will impact on groundwater resources, that is reductions in groundwater levels may lead to increases in water table gradient and accelerate groundwater movement onto the project area. The impact of this is unknown.
- Use of abstracted groundwater in the project area has the potential to impact on surface water quality if discharge occurs to the receiving environment. Several indicators in groundwater exceeded WQOs and recorded poorer water quality than in surface waters of the project area.
- The existing farm homestead is connected to a septic tank system. The condition of the septic system and potential influence on groundwater is unknown. Future impacts from the septic system can be negated by connecting the farm homestead to the WWTP and removing the septic tank system.

These potential impacts to surface water and groundwater are expected to be mitigated through appropriate on-site management of hazards (for example through a Hazardous Substances Management Plan and Environmental Management System, compared with SDS 2017), with spills contained and cleaned up. Potential impacts to the receiving environment will be further mitigated by the capture and treatment of site waters through stormwater management (WSUD) and a waste water treatment system. An ESCP will be developed for construction and operation to minimise erosion and sediment loss. Nutrient loads from the WWTP discharge will be offset by improving water quality through environmental works in the catchment that receives discharge and rehabilitation plans for improving frog habitat are expected to have a positive impact. In this regard, the Queensland *Draft Point Source Water Quality Offsets Policy 2017* may have application. Where on-site treatment alone is unlikely to allow direct discharge and achievement of the management intent as defined in the EPP (Water), additional mitigation measures have been proposed.

In addition to the above, the construction of in-stream structures (temporary or permanent) has the potential to create barriers to fish passage. Waterway barrier mapping, relevant to assessing risk of impact to fish movement, is shown on Figure 9-3. The threats to fish passage posed by instream structures will be considered during the detailed design phase. Designs shall aim to avoid impacts on fish passage.

9.5.1.2 Waste water

Waste water will be treated differently in Stage 1A compared to the remainder of the project stages. For Stage 1A, it is proposed that on-site primary or secondary treatment systems (Biolytix, Biocycle or similar) are installed in individual lots. For Stage 1B and beyond, a WWTP will be installed to take all project waste water (including connection to Stage 1A properties). This will include tertiary treatment (nutrient removal) achieving class A+ quality effluent with low nutrient concentrations.

At all stages, it is proposed that land application is the primary means of disposing of treated waste water effluent. Until the completion of the Golf Course, effluent can be used to irrigate existing paddocks. Once the Golf Course is completed, effluent will be used for irrigation to minimise the non-potable water demand on the site. The proposed waste water treatment systems are described in EIS Chapter 7.

The model for effluent disposal using land irrigation (MEDLI V2.0) developed by the Queensland Department of Science, Information Technology and Innovation (DSITI) was used to determine the capacity of the plant soil system to assimilate the nutrients and salt applied (including potential risks to groundwater quality) and the capacity of the effluent irrigation systems to dispose of the effluent generated by the project (that is need for and magnitude of discharge and potential risks to surface water). The KUR-World Effluent Irrigation Feasibility Study (NRA 2017e) provided details of the assumptions made and the scenarios modelled. These may differ from the final proposed WWTP design specifications, but modelling was designed to inform the design process. A summary of outcomes as they relate to potential impacts to surface waters are presented below.

9.5.1.3 Groundwater

No potential adverse groundwater impacts were identified under any of the effluent irrigation scenarios modelled for all stages of the project. Provided that irrigation occurs on land that is suitable for receiving irrigation, the land is used for agriculture or amenity planting, and effluent quality and quantity is similar to that modelled in NRA (2017e), no adverse impacts to groundwater values are expected in the long-term.

9.5.1.4 Surface water

Simulations have indicated that under the conditions modelled, not all effluent can be disposed of by land irrigation alone. The proportion that can be re-used decreases with increasing effluent generation rates and decreases as the project progresses.

The greatest threat posed by effluent irrigation is not due to effluent re-use, but due to the impact of the effluent that cannot be re-used and must be disposed of. If effluent that is surplus to demand is disposed of in waterways on the project site, it has the potential to impact on water quality and environmental values contrary to the intent of the EPP (Water). According to the modelling, the likelihood, nature and scale of any potential impact to surface water increases as the project develops.

The change in water quality caused by effluent discharge may have an impact on stream-dwelling fauna. The potential changes in water quality will be flow dependent, and discharge will tend to occur in pulses. Many organisms can tolerate poorer water quality for short periods. The effects of pulse exposures are toxicant and species dependent. If organisms do recover between pulses, then the rate of recovery relative to the frequency of exposures is important. If the organisms do not recover (or have not fully recovered) from an initial pulse, the effects of subsequent pulses are likely to be cumulative (and could be greater than additive). In work on impacts of major ion (magnesium) pulses, Hogan and others (2013) and Prouse and others (2015) found that organisms could recover rapidly between pulses. Therefore, any management measure that can minimise the duration and frequency of pulse events will minimise potential impacts.

There is insufficient information available to quantify the impact, but the potential level of impact is expected to increase as the size of the development increases through the proposed project stages. With the information available, the upper range of average dry weather flow (ADWF) values estimated by ARUP (personal communication with Sam Koci, Senior Engineer, ARUP, 25 September 2017) and used for modelling purposes on the whole produced estimated nutrient export loads of more than 10% of background[3] under most scenarios from Stage 1B onwards.

The following sections summarise the potential threats as they relate to water quality and aquatic ecology.

9.5.1.4.1 Stage 1A

Effluent re-use of >95% and infrequent overtopping events (<1 /year) could be obtained under low range ADWF conditions with relatively modest storage volume and land areas combinations. However, with 90% effluent re-use achievable under the high range ADWF scenarios with similar storage and land area combinations, it was estimated that discharge loads have the potential to increase TP loads leaving the project site by over 10%. The impact due to TN export is smaller, but the impact due to dissolved inorganic nitrogen may be similar to that of TP.

This modelling, undertaken in NRA (2017e), was based on the availability of 1-5 ML storage capacity. It is understood that this storage volume is not feasible during Stage 1A (personal communication with Samuel Koci, Senior Engineer, ARUP, 17 November 2017). A reduced storage capacity will result in a decrease in the proportion of total effluent that can be re-used, increasing the volume discharged to the receiving environment during Stage 1A.

NRA (2017e) noted that plans to revegetate two eroding areas (associated with Paintball activities and the Helipad) that may be contributing sediment and associated nutrients to the Owen Creek system would likely be sufficient to potentially offset most of the additional TP loads in discharge as a result of Stage 1A. Under low ADWF scenarios, the volumes of discharge are relatively small, the frequency of discharge events is low and the likely flow conditions during discharge in the receiving waters are high. Impacts on receiving water quality will be transient and may not be significant (see mitigation measures).

9.5.1.4.2 Stage 1B

Low range ADWF discharge and 40 hectares of irrigation was estimated to produce between 1-5% of TN loads and 5-10% of TP loads resulting from background land uses on the project site. TP loads could be further reduced to between 1-5% of background by ensuring low rates of stormwater inflow into the WWTP. As in Stage 1A, the land management offsets would likely be sufficient to potentially offset most of the additional TP loads in discharge as a result of Stage 1B.

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[3] In this case, background loads have been estimated from Source Catchments modelling inputs used to calculate nutrient loads entering the Great Barrier Reef Lagoon from the Wet Tropics region under different land uses (Hateley and others 2014).

Under high range ADWF, TN load contributions of more than 10% of background were estimated unless a large land area (at least 80 hectares) is irrigated. None of the scenarios with high range ADWF estimates achieved TP loads of 10% of background.

Although the WWTP will be installed in Stage 1B, leading to an improvement in effluent quality, because of the increased ADWF, the potential for discharge impacts is higher than in Stage 1A under the conditions simulated.

9.5.1.4.3 Stage 2

Until the Golf Course is completed, there may be a need to use paddocks for irrigation during Stage 2. After the Golf Course has been constructed in Stage 2, this area and other areas of amenity planning will be irrigated with treated effluent.

If paddocks are used, modelling indicates that very large areas would be required to manage effluent under the high range ADWF, but that impacts >10% on nutrient loads in the receiving environment would be likely even with 100 hectares of irrigation. Outcomes under the low range ADWF scenarios would be better with 60 hectares irrigation required to allow almost 80% effluent re-use resulting in TN export loads of less than 10% of background. Under all scenarios, TP export loads remained >10% of background.

With the Golf Course finalised (and available irrigation area now finite), TN discharge loads were modelled below 10% of background and TP discharge up to 20% of background in all low range ADWF scenarios. This compared to TN discharge of up to 40% of background and TP in excess of 100% of background for the high range ADWF.

9.5.1.4.4 Stage 3

TN discharge was below 10% of background and TP discharge up to 25% of background in all low range ADWF scenarios. This compared to TN discharge of up to 47% of background and TP in excess of 100% of background for the high range ADWF.

9.5.2 Management measures – groundwater

The following management measures are required to minimise impacts to groundwater from effluent irrigation and/or stormwater management.

- Only land identified as suitable for irrigation should be used for effluent disposal.
- Appropriate buffer zones/set-backs nominated in the report should be applied around creeks.

9.5.3 Management measures – surface water and aquatic ecology

There are several ways to reduce or remove potential impacts associated with effluent discharge and/or stormwater management that need to be explored at the detailed design stage of the WWTP.

- Increase storage volume and irrigated land area
- Reduce nutrient content in effluent to the lowest practicable extent
- Reduce stormwater and effluent production:
  - use water saving and efficiency measures on-site
  - identify non-potable uses other than irrigation
  - irrigable land with moderate slopes (12-20%) should be managed and land condition monitored to prevent run-off and accelerated erosion
  - reduce stormwater infiltration into the sewerage system through appropriate design, build specification and maintenance.

- Explore options to discharge surplus WWTP water to other on-site creeks less sensitive to impacts than Owen Creek (such as Cain Creek).
- Explore options for waste water and/or effluent discharge off-site into a less sensitive or already impacted waterway (such as the current location of the Kuranda WWTP outfall or the Barron River).

Any design that includes on-site effluent discharge must be accompanied by more detailed hydrological modelling to determine the potential impact on receiving water quality.

9.5.4 Stormwater

The proposed stormwater drainage strategy for KUR-World will overlap and replace elements of the erosion and sedimentation control measures for construction and operational phases presented in Section 9.7 . The stormwater drainage strategy developed for the project area (ARUP 2017) provides the following WSUD management measures.

- Run-off captured from building roofs will be conveyed to rainwater tanks for re-use, with tank overflows draining to vegetated swales. Rainwater captured in tanks will be used for toilet flushing and irrigation.
- Run-off from all other catchment areas will drain directly to grassed swales and vegetated buffers.
- Within the more intensely developed commercial/retail/educational areas, stormwater will be treated by proprietary stormwater improvement devices prior to draining to the swales.
- Road run-off will be collected in a conventional kerb and channel/pipe and pit stormwater drainage network and will be treated by proprietary stormwater improvement devices prior to draining to swales and retention basins.
- Gross Pollutant Traps will act as primary treatment for each catchment to target litter capture.
- Gross Pollutant Traps flow to swales, which flow to bioretention basins with discharge to creeks from multiple locations across the project area (personal communication with Priyani Madan, Water Engineer, ARUP, 18 October 2017).

Stormwater volumes will be managed to minimise flows and nutrient loads discharged to waterways. It is understood that stormwater discharges will be managed, where possible, to mimic pre-development discharge conditions (that is no significant net change in site run-off volume).

ARUP (2017) modelling of the proposed stormwater strategy, which has been developed to meet the Development Manual for Stormwater Quality Management 2014 (FNQROC 2014), estimates the following residual loads in discharge water (that is reductions achievable compared to load estimates from the project without implementation of WSUD).

- 934 ML/year flow (11.3% reduction in discharge to the receiving environment).
- 9.8 mg/L TSS (94.2% reduction in developed site pollutant loads).
- 0.132 mg/L TP (66.3% reduction in developed site pollutant loads).
- 0.95 mg/L TN (69.3% reduction in developed site pollutant loads).
- 0 kg/year gross pollutants (100% reduction in developed site pollutant loads).

The design objectives for stormwater quality management applicable to the Wet Tropics region have been met by the proposed stormwater strategy (ARUP 2017). However, the modelled concentrations after treatment exceed WQOs for base flow and high flow conditions for total phosphorus (0.025 mg/L and 0.05 mg/L, respectively) and total nitrogen (0.34 mg/L and 0.668 mg/L, respectively) in surface water (Table

9.3.1.2), with the exception of TSS, which is comparable to the base flow WQO (8 mg/L) and below the high flow WQO (52 mg/L).

Modelled discharge nutrient and suspended sediment concentrations from the proposed stormwater strategy also exceed those recorded under high flow conditions at background and benchmark sites, with the exception of site SW09, which receives run-off from upstream operations.

Although the proposed WSUD meets the recommendations in FNQROC (2014) for reductions in load estimates from the project without implementation of WSUD, expected stormwater discharge will exceed WQOs and the water quality measured in the receiving environment for some indicators. Water quality in the receiving environment will therefore be impacted by the proposed stormwater drainage strategy.

9.5.5 Management measures – surface water and aquatic ecology

There are several ways to reduce or remove potential impacts associated with stormwater management that need to be explored at the detailed design stage of the stormwater management features.

- Offset the nutrient loads from stormwater discharge by improving water quality through environmental works in the catchment that receives discharge.
- Reduce stormwater loads by minimising stormwater generation and enhancing nutrient and suspended solids removal by amending design specifications of proposed management features or installing additional features.

Detailed design must be accompanied by more detailed hydrological modelling to determine the mitigation measures require to protect receiving water quality and aquatic ecosystems.

9.6 Water Quality Management Plan for existing and proposed water bodies

This plan is designed to assist in the management of the farm dam and any other water bodies that may be developed in the project area. The farm dam is currently used for stock water supply and is planned to provide part of the aesthetic appeal of the KUR-World Farm Theme Park. In addition, the dam is proposed to be used as a wet weather storage overflow for treated effluent water from the WWTP, which will be used as a supplementary non-potable water supply. The farm dam will also provide some polishing of the stormwater and treated waste water prior to discharge. This will be achieved through settlement of suspended particles and the actions of the biological components of the system on the sequestration or degradation of potential pollutants.

The dam is not intended for recreational use involving primary contact (such as swimming), but it is expected that contact with the dam waters cannot be avoided altogether, especially if children play near the water's edge. For this reason, the management of the dam will aim to retain a quality of water that is suitable for secondary contact (the degree of contact associated with such activities as fishing or sailing when the body is not usually in intimate contact with the water but may come into indirect contact through splashing or handling materials that have been in contact with the water). Management of the dam will also aim to retain the aesthetic quality of the feature and to minimise the risk of mosquito breeding.

The plan presents dam design considerations and maintenance schedules required to meet the following objectives:

- water quality management
- vegetation management
- mosquito management.

The structure of the plan is as follows.

- Section 9.6.1: Provides a background to water quality management and how it can be achieved.
- Section 9.6.2: Describes aquatic weeds and their management.
- Section 9.6.3: Describes mosquito vector management.

A management plan will be developed for operational maintenance of the farm dam and any other water bodies that may be developed in the project area.

9.6.1 Background information

9.6.1.1 Water quality management objective

Water quality discharges are managed to meet the management intent of the EPP (Water) to ensure that discharged water progressively improves physical or chemical indicators in the receiving environment to achieve WQOs. Water quality within on-site structures should be managed to achieve this outcome.
The farm dam has not been specifically designed to provide habitat for particular flora and fauna, but it is expected that by attaining water quality and other objectives, the conditions created will promote the colonisation of the dam by native biota. Nevertheless, the presence of nuisance organisms that may compromise the visual quality of the dam or other management objectives will be controlled

9.6.1.1.1 Threats to water quality

The farm dam may receive a number of inputs that may contain pollutants. These pollutants may include:

- nutrients and suspended solids from WWTP effluent
- litter
- suspended solids (largely soil) from the proposed development, including the Farm Theme Park and Equestrian Centre
- nutrients and microbiological contaminants from faeces of domestic and wild animals.

9.6.1.1.2 Achieving management objectives

The following management measures will be taken to manage receiving environment water quality and other potential impacts.

9.6.1.1.3 Design and Management

The following design aspects are incorporated into the stormwater drainage system and WWTP, or are recommended for the farm dam, to facilitate achievement of the water quality management intent in the receiving environment.

- Tertiary treatment of effluent waste water to achieve low nutrient content and A+ quality.
- A deep water zone (approximately 4 metres deep) where further sediment (and associated metal pollutant) settling is achieved. The re-suspension of settled sediment due to wind induced turbulence is also minimised in deeper waters. The actions of UV rays in open water contribute to disinfection of pathogens.
- Installation of a power supply will be considered for use in the future should the addition of aeration devices to the dam be required. If stagnation or stratification (the creation of an anaerobic layer at the bottom of the dam which can release nutrients associated with settled sediments) are found to occur in the dam (through appropriate monitoring), aeration equipment will be installed. This will increase turbulence and reduce the risks of algal bloom development. Aeration would also provide an additional management technique for the control of mosquito populations.

9.6.1.2 Water quality targets

Aesthetic targets have been developed for the farm dam and other on-site water bodies to meet the management intent in the receiving environment. WQOs for the receiving environment (Table 9-2) can be used as a guide to management, but do not apply to these waters. The water quality targets are presented below.

- The dam should be substantially free from floating litter, scum, foam and other objectionable matter.
- Oil and petrochemicals should not be noticeable as a visible continuous film or sheen on the water nor should they be detectable by odour.
- The dam should not produce an objectionable odour.
- The dam should be free from algal blooms and dense mats of aquatic plants.

9.6.2 Aquatic weeds and their management

Vegetation is expected to form an integral part of the design and aesthetic quality of the dam. It is to be expected that vegetation within the dam will change over time. However, changes that diminish the overall aesthetic quality of the dam, or that allow the invasion of undesirable or noxious plants, must be managed.

9.6.2.1 Vegetation management objectives

Vegetation management has the following objectives:

- maintain or enhance aesthetic quality
- maintain water quality objectives
- minimise weed invasion
- minimise mosquito breeding opportunities.

9.6.2.1.1 Achieving management objectives – weed control

A number of aquatic weeds (for example Salvinia (*Salvinia molesta* and other species), water hyacinth (*Eichhornia crassipes*)), that are of significance at the National, State or Local level occur in the area and may invade the dam. The identification and control of weeds relevant to the project area are covered by the following.

- Weeds of National Significance (WoNS) (DoEE 2017)
- Queensland *Biosecurity Act 2014*
- *Wet Tropics Management Plan 1998*
- Mareeba Shire Council Local Area Pest Management Plan 2015 to 2020 (MSC undated).

Weeds may affect the aesthetic quality of the dam and also compromise other dam management objectives. For example, dense growth of weeds can provide suitable habitat for mosquito breeding. Any dense weed growth at or near the water's edge is therefore undesirable and should be controlled.

9.6.2.1.2 Weed management

Weed management actions should be targeted to the specific weeds encountered. Fact sheets available from the Queensland Department of Agriculture and Fisheries provide descriptions, legal requirements and control measures for weeds that may occur around on-site water bodies. Where specific control details are not available, the Department of Agriculture and Fisheries should be contacted for further control options.

9.6.3 Mosquito management

Wetlands, lakes and dams provide habitat for invertebrate fauna including mosquitos. As well as being a nuisance, some species of mosquito are vectors for diseases such as Dengue and Ross River virus and

therefore pose a potential public health risk. Mosquitos are widespread throughout Queensland and occur naturally in coastal and freshwater environments.
New developments that include water features have the potential to increase the risk of humans or host animals coming into contact with mosquitos, but artificial wetlands and dams can be designed and managed to minimise mosquito breeding. Some compromises in terms of habitat creation for other fauna may be required, but in this case these compromises should not affect the overall function of the dam.

9.6.3.1 Mosquito management objective

The mosquito management objective is to minimise the opportunities for mosquito breeding, primarily through appropriate dam design and management.

9.6.3.2 Threats to mosquito management

The following environmental conditions increase the likelihood of mosquito and other biting insect breeding and survival.

- Large areas of shallow water that drain slowly when water levels recede.
- Muddy or sandy banks and beaches.
- Dense vegetation that protects larvae from predation.
- Low predator populations due to age (that is length of establishment) and/or unfavourable conditions.
- High nutrient inputs (normally associated with waste water rather than stormwater).
- Still surface conditions (sheltered from surface disturbance) and low flows.
- Presence of large amounts of emergent, floating or dead vegetation or the presence of algal mats on the water surface.
- Irregular edges to dam/wetland that may allow the development of stagnant pools.

9.6.3.3 Achieving management objectives

9.6.3.3.1 Design and management

Based on the threats listed above, the following aspects are to be considered in the design of water bodies.

- Extensive areas of deep open water free of emergent vegetation to minimise mosquito habitat and egg laying sites (depths in excess of approximately 2 metres are required to minimise growth of emergent vegetation[4]).
- Provision of a top up water source to allow manipulation of surface water level where necessary. Water levels should not fall below 600 millimetres depth. Water levels will be deeper than this during periods of high rainfall.
- Minimise barriers to the prevailing winds. Wave effects disrupt surface tension and cause larvae to lose their hold on the water surface and drown. Wave action also potentially provides unsuitable conditions for egg laying.
- A monitoring and maintenance programme for removal of excessive vegetation growth, removal of dead or decaying vegetation and removal of floating vegetation/algal mats.
- Aim to maintain favourable water quality to encourage predator colonisation and survival. Once the dam is established and water quality data is available, consult with the Department of Agriculture and Fisheries regarding the introduction of appropriate native fish species to enhance biological control of mosquitos.
- Minimise exposed muddy banks.

[4] The dam is currently approximately 4 metres deep and it is anticipated that a depth of at least 2 metres will be required to maintain aesthetic value. This aspect should be self-regulating.

- Minimise irregularities in the dam margin (within the constraints of creating an aesthetically pleasing design) to avoid creating stagnant pools.
- Access to a power supply that can be used in future for active aeration of the dam and to provide an additional source of wave action should this prove necessary.

9.6.3.3.2 Maintenance

Preventative maintenance procedures will be used as the primary control measure for mosquitos. These procedures are presented in EIS Chapter 21, Environmental Monitoring and Management Plan.

9.6.3.3.3 Mosquito control

Where routine maintenance procedures alone cannot prevent a serious increase in the adult mosquito population and in situations where there is a public health risk, mosquito control agents (either biological or chemical) may be required. Any mosquito control programme that requires the use of agents should be developed in consultation with Mareeba Shire Council and conform with the Mosquito Management Code of Practice for Queensland (LGAQ 2014).

9.7 Erosion and sedimentation controls during construction and operation phase

The results of investigations conducted to collect relevant soils data together with the broad environmental setting (refer to EIS Chapter 3) inform the planning of management practices for erosion and sediment control (ESC) and are summarised below.

The issues associated with the construction of the farm dam in the upper reaches of an unnamed tributary of Owen Creek (NRA 2016), together with the corrective actions that followed, are collectively instructive to the planning of management practices. Equally, the knowledge and industry experience gained from the planning and implementation of ESC measures elsewhere in the region has application. This site, regional experience and industry knowledge inform ESC planning of management practices for the project necessary to avoid or mitigate impacts commonly associated with land disturbance in north Queensland.

9.7.1 Environmental setting

This section provides an overview of the environmental conditions of the KUR-World Project pertinent to developing the site-specific requirements for ESC.

9.7.1.1 Seasonal conditions

Seasonal and climatic conditions have a significant effect on erosion, sediment and drainage control. In particular, heavy rainfall can worsen erosion or increase the likelihood of sediment-laden run-off entering waterways and impacting on downstream aquatic habitats.

9.7.1.2 Soils

The dominant soil types identified by NRA (Refer Appendix 1, Soils and Geology) for the KUR-World project are Galmara and Bicton, described by Malcolm and others (1999) and Murtha and others (1996). Appendix 1 provides the following information related to soil erodibility and fine sediment export potential (see EIS Chapter 3, Section 3.4 for additional detail).

The soils likely to be disturbed during development are non-sodic and are not expected to be prone to tunnel erosion. The undisturbed topsoils over much of the site are relatively stable, particularity when good vegetation cover is maintained. Upper subsoils are moderately erodible, but deeper subsoils are highly or very highly erodible in Galmara soils (below 75 centimetres) and Bicton soils (below 50 centimetres). If deeper subsoils are exposed during earthworks, particular attention will be required to manage erosion risks. Both major soil types have a high fines (silt and clay) content and there is a risk of fine sediment being mobilised from eroding soils into the receiving environment. The subsoils have other properties that may hinder revegetation efforts. Failure to take these soil properties into account during revegetation works may lead to poor plant establishment, limited groundcover and accelerated erosion.

Engineering design and bulk earthworks planning should consider minimising cut and fill operations that would expose highly erosive subsoils.

9.7.1.3 Receiving environment

The EVs for surface waters of the project area receiving environment are outlined in Table 9-1. Furthermore, listed Threatened species, including the Kuranda Treefrog (*Litoria myola*) and Tapping Green-eyed Frog (*Litoria serrata*), are known to occur in the direct receiving environment of the project area and are sensitive to potential impacts related to water quality and sedimentation (Refer Appendix 5).

9.7.1.4 Erosion and Sediment Control risk

9.7.1.4.1 Technical

Based on the known soil properties, high rainfall, sloped surfaces and presence of sensitive aquatic environments, soil disturbance associated with the proposed KUR-World project poses a high risk of causing soil erosion and sediment loss issues. Exposure of subsoils to rainfall is a particularly high erosion risk at the site.
The areas of the site that have the highest risk of ESC-related issues are as follows.

- Areas with moderate to steep slopes.
- Areas in or near drainages features and waterways.
- Areas where subsoils are exposed during earthworks.
- Large containment structures.
- Locations where site affected waters leave the property.

9.7.1.4.2 Non-technical

Beyond the technical based risks described above, are those specific to project and people management. Based on experience, the key to the avoidance of predictable ESC related issues is effective project management. Appropriate management practices (that is planning, design, installation, maintenance, monitoring and corrective actions) require effective implementation. Given project delivery will involve third parties beyond the proponent, commercial contractual aspects are critical to project management. A known limitation to effective project management is disconnection between the project phases integral to project delivery. Disconnections can occur due to changes in entities and personnel, with this limitation escalating as the project delivery timeframe extends.

Experience in north Queensland is that even when ESC measures are conditioned in regulatory approvals, this alone does not always deliver adequate protection. Resources need to be directed to the development of a strategic approach to managing the known risks and sensitivities at this site. The following section presents a framework to be adopted for the project.

9.7.1.4.3 Erosion and Sediment Controls

9.7.1.4.3.1 Strategic

An appropriately qualified professional should be engaged to prepare an ESCP for the construction and operational phases of the project. Measures identified in the ESCP should be developed in accordance with the *Best Practice Erosion & Sediment Control* guidelines (IECA 2008). The ESCP should be certified by a Certified Professional in Erosion and Sediment Control (CPESC).

The ESCP should be integrated into the planning, design, construction (including to the practical completion and defects period) and maintenance phases for each built component of the project.

- Mandatory 'hold points' are to be identified and incorporated into project scheduling documentation.
- Punitive measures for non-conformance with 'hold points' should be included in contractual documentation in a form and style known to prove effective in providing a meaningful incentive to achieve conformance.
- Integration should be demonstrated in project scheduling documentation and in key deliverables including, though not limited to, invitation to tender for works, planning and design documentation, and 'as-built' documentation.

The approach to overall project delivery should be selected having afforded significant weight to the importance of demonstrated efficacy of ESC. This should include the use of contractual tools used elsewhere to manage known limitations to effective ESC in north Queensland; for example, include ESC devices and materials as provisional items in contracts.

The performance monitoring of ESC measures, and changes to the construction schedule or methods, will necessitate changes to the ESCP. The modifications to the ESCP may be considered minor, moderate or significant. It is expected that significant modifications will be the exception, whereas moderate and minor changes will occur. A change management mechanism is to be included in the ESCP.

In addition to sequencing the ESCP into the planning, design, construction (including the practical completion and defects period) and maintenance phases for each built component of the project, the land disturbance activities associated with the project (that is clearing and grubbing and bulk earth works) should be scheduled to occur in months that do not experience high rainfall. Where this is not practicable, additional resources will need to be devoted to ESC measures.

The suggested performance standards for the ESC measures are as follows.

- Implementation of ESC measures, as demonstrated by adherence to documented Inspection Test Plans (ITPs).
- Water released from site should be tested for total suspended solids (TSS). Although recommendations in IECA (2008) for ESC performance nominates TSS should not exceed 50 mg/L, a value applied in north Queensland, this standard is not appropriate for this project. NRA (2017a) concluded that the performance measure for affected waters entering the receiving waters is TSS to not exceed 8 mg/L (excluding the volatile fraction). ARUP (2017) concluded that the stormwater drainage strategy for the project, developed to meet the requirements of the Development Manual for Stormwater Quality Management (FNQROC 2014), demonstrated achievement against the TSS criteria. Although accepted practice, this approach defines performance by achievement of a load reduction, rather than achievement of a WQO. The performance measures required to protect receiving waters are therefore different. The apparent achievable TSS concentration in stormwater after the application of WSUD measures at the project site is approximately 10 mg/L. The recommended target for ESC in terms of affected waters discharging to receiving waters is a TSS of 8 mg/L. On balance, a concentration of 10 mg/L should serve as a trigger value that, if not met, serves as a prompt to review of ESC measures and as necessary implement corrective action, maintenance or additional measures. A TSS of 25 mg/L serves as an indication of non-conformance for which corrective measures are necessary (TSS excludes volatile fraction).
- Standards solutions of different TSS concentrations should be created and kept on-site for visual comparison with site water (to overcome delays due to laboratory analysis associated with TSS determination).

- Achievement of 80% groundcover on disturbed areas not draining to ESC measures by 1 November each year.
- With respect to designs, the acceptable design solutions relevant to the project published by Far North Queensland Regional Organisation of Councils (FNQROC 2014) are reproduced below (where ARI is Average Recurrence Interval):

All erosion and sediment control structures, channels, catch drains, diversion drains, etc. shall be designed for an appropriate storm event. The minimum design criteria are shown in Table 9-6 below. Design capacity excludes minimum 150mm freeboard:

Table 9-6 ESC Structures - Design Criteria

	Design Life	ARI
Non-erosive design capacity	0-6 months	1 year
	6-12 months	2 years
	12-24 months	5 years
	≥24 months	10 years
Structural stability	0-6 months	5 years
	6-12 months	10 years
Temporary culvert crossing	-	1 year

9.7.1.4.3.2 Construction and operational

All construction earthworks must be conducted within the framework of the core principals of ESC. A summary is provided below.

Project planning:

- Understand the particular risks on the site as identified in this report.
- Integrate ESC practices and measures into the overall project construction schedule.
- Incorporate mandatory hold points (used to verify appropriate implementation of critical elements of the ESCP) into the overall project construction schedule.
- Understand that the ability to retain sediment-laden water on-site in containment structures during the wet season is limited.
- Schedule earthworks to avoid or minimise works in high rainfall months.
- Establish routine plans to manage risk during stop work periods (that is end of shifts, overnight, weekend and public holidays).
- Establish clear lines of responsibility.
- Provide sufficient resources to implement the ESCP.
- Have contingency plans in place for extreme weather events (for example cyclones) during the wet season and unexpected/unseasonal rainfall during the dry season.

Drainage control

- Divert clean water around the site in a safe manner using appropriately designed structures.
- Divide the site's catchments into smaller sub-catchments to reduce the amount of water that requires management and improve the efficiency of sediment control structures.
- Minimise flow velocities of run-off on disturbed/bare ground through the use of measures such as surface roughening, check dams, contour banks and diversion banks. Select fit-for-purpose structures for each area in accordance the ESCP.
- Direct dirty water to on-site structures designed to settle or otherwise treat suspended sediment.

Drainage control

- Minimise vegetation clearing extent via planning and implementation of systems/controls during construction and operation (for example permit to clear system, clearly marking clearing extents prior to disturbance, designate and install appropriate site entry and exit points).
- Develop a topsoil management plan and strip and store topsoils and subsoils separately.
- Soil stockpiles are to be stored at least 50 metres away from drainages or drainage features. Divert upslope water around stockpiles and install sediment fencing on the downhill slope of the stockpiles. Establish cover on the stockpiles where they are left in place for longer than nominally 1 month during the dry season or nominally 5 days during the wet season (to be confirmed in the ESCP). Retain a maximum stockpile height of 2 metres.
- Avoid or minimise disturbance and exposure of high risk soils.
- Replace stored topsoil or, as required, ameliorate exposed subsoils prior to or as part of revegetation works.
- Establish vegetative or other forms of groundcover (for example natural fibre matting, mulch or rock) on areas with exposed soil as soon as is practicable, but at least prior to the wet season. A minimum target of 80% cover is recommended (to be confirmed in the ESCP). Soil surface preparation techniques (such as dozer tracking) can assist in minimising erosion prior to vegetation establishment.
- Select appropriate vegetative cover species in accordance with the ESCP.

To promote successful revegetation, undertake soil amelioration to address limiting soil properties as required, particularly where subsoils are not covered with suitable topsoil (refer to NRA 2017b).

Sediment control

- Install appropriately designed and constructed sediment control features or structures in all locations where sediment may be generated (for example silt fencing around stockpiles, check dams in drainage lines, formal sediment traps or basins).
- Final sediment control structures such as sediment traps and/or sediment basins are to be designed and constructed in a manner that retains water for a sufficient period to reduce the amount of suspended sediment in the water column prior to entering the receiving environment. In terms of removal of fine sediment, the use of chemical treatment may be needed depending on the quality of water on-site and targets for release set through the ESCP. Chemical treatment of sediment-laden water should be undertaken with caution, and appropriate investigations undertaken in relation to potential impacts associated with the treated water quality on the receiving environment (for example some flocculants may contain contaminants that could be harmful to the receiving environment).
- Plan locations for significant structures so that they can be incorporated into the operational stormwater drainage strategy if required.
- Maintain sufficient storage capacity in sediment control structures prior to the wet season and following significant flow events.

- Locate vehicle wash-down points away from watercourses. Ensure wash-down points are designed to capture and manage soil material removed from site vehicles.

Monitoring and management

- Ensure sufficient materials for ESC measures are retained on-site in a secure location.
- Inspect, maintain or repair ESC measures following run-off events (rainfall trigger to be nominated in the ESCP). Review the adequacy of the ESC measures prior to each wet season, and implement alterations or reparations prior to 1 November each year.
- Undertake maintenance of revegetated areas to retain suitable cover and species composition.
- The ESC maintenance schedule is to remain in place until areas are signed off as completed and stable in accordance with the ESCP specifications.
- Monitor the performance of ESC measures against measurable criteria (for example discharge water quality targets) as nominated in the ESCP.

The greatest risk of ESC-related issues occurs during the construction phase. Measures for this are provided in the above sections. During operation of the KUR-World project, the site should have well established cover with no large areas of exposed soils that require ongoing management, and therefore, the risk of ESC-related issues would be significantly lower during this period. However, ongoing maintenance will be required for revegetated areas and permanent structures in accordance with the operational ESCP and stormwater drainage strategy.

9.8 Monitoring and measurement plan

The following monitoring and measurement plan has been developed to demonstrate how the achievement of WQOs would be monitored and audited, and how corrective actions would be managed.

If an emergency occurs (such as a chemical or fuel spill into on-site stormwater or sediment controls, water bodies or to the receiving environment) Emergency Services should be contacted in the first instance. The Queensland Department of Environment and Heritage Protection (EHP) should also be contacted if it is evident that environmental harm has been caused or there is a potential for environmental harm to be caused. Under the Queensland *Environmental Protection Act 1994*, a person must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm. Similarly, employees have a duty to notify their employer of any environmental harm that has actually happened or can potentially occur as part of their activities.

The operation of a WWTP is an Environmentally Relevant Activity (ERA 63 – Sewage Treatment Plant) and will require an Environmental Authority (EA) under the EP Act. This may mandate a Receiving Environment Monitoring Programme (REMP). The following can be used as the basis for a REMP.

9.8.1 Surface water

Surface water quality data is essential for understanding the impacts of an activity on receiving waters and is the primary indicator used in REMPS (EHP 2014b).

9.8.1.1 Analytical suite

It is recommended that the analytes monitored during the baseline surface water quality monitoring programme (NRA 2017a) are used for future monitoring, with the addition of hydrocarbons (associated with vehicle use on bitumen roads) and microbial indicators (related to the operation of the WWTP). This expanded suite of analytes was selected to provide information on the surface water quality characteristics likely to be influenced by the development. Key risks identified for surface water quality are related to: run-off from cleared areas during the construction phase; stormwater from roads, roof tops and hard stand areas; and nutrient inputs from waste water treatment, farm theme park and equestrian centre, horticultural and animal housing areas; and the application of fertilisers to landscaped areas.

Where the use of pesticides is introduced to the Golf Course or landscaped gardens, or for termite control, the analyte list should be updated to include the specific pesticides known to be in use.

A number of analytes were not detected (that is were recorded below laboratory limit of reporting (LOR)) during baseline surface water monitoring. Some analytes could be removed from future monitoring programmes if it can be demonstrated that they are not impacted by site activities.

9.8.1.2 Sites monitored

Project area surface water monitoring sites (SW01, SW09, SW02, SW02B, SW03, SW04, SW06 and SW08) are recommended for inclusion in the routine monitoring programme (Table 9-7, Figure 9-5), as well as additional sites where the specific location of discharge infrastructure is known (for example downstream of WWTP, ESCP or stormwater discharge points).

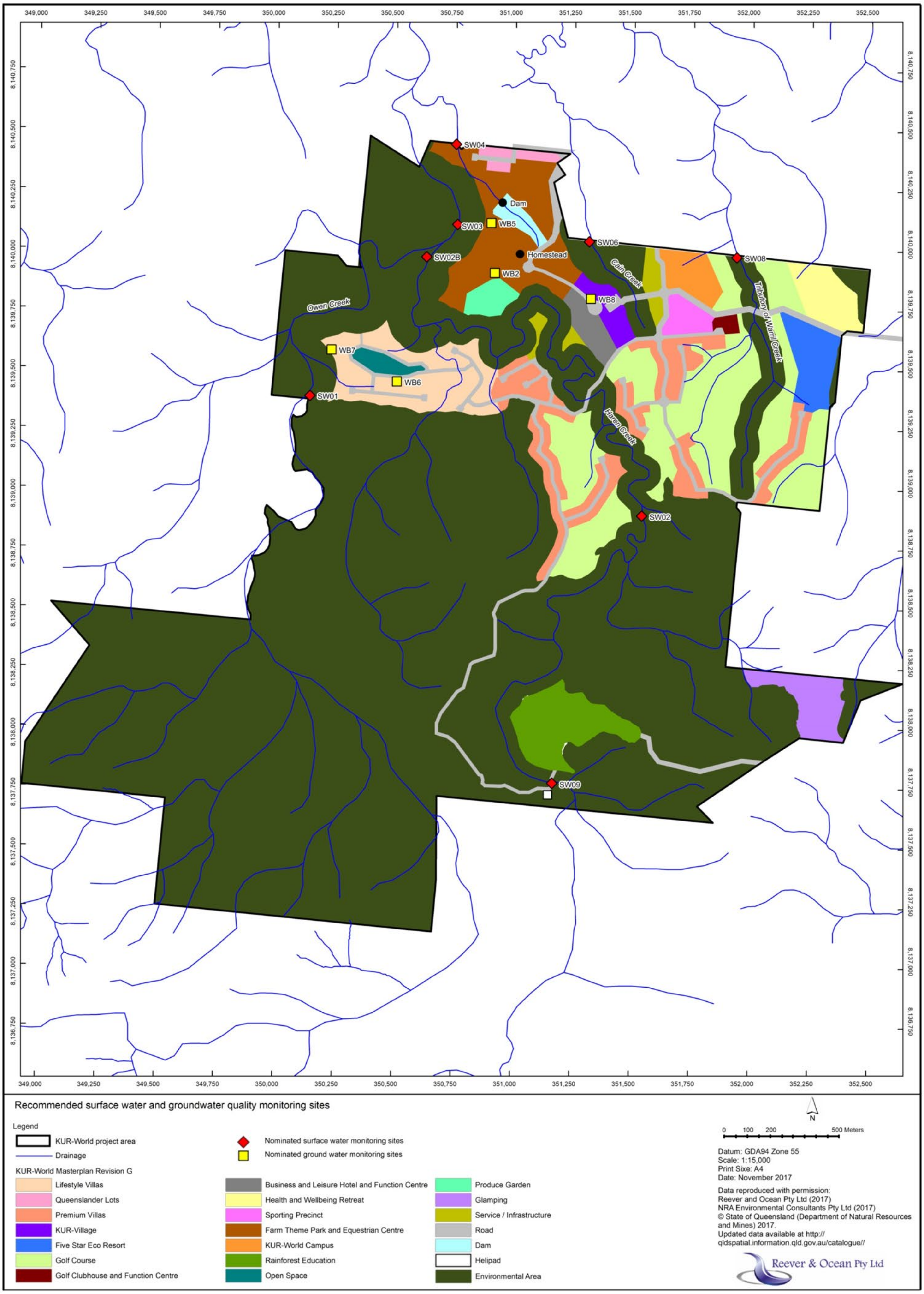
Monitoring sites may change between construction and operational phases depending on the source of potential discharge and impact. Monitoring sites included in the routine programme should be reviewed prior to commencement of each stage of project development and on completion of the construction phase.

Table 9-7 Justification for inclusion of surface water quality monitoring sites.

Site	Purpose	Justification
SW01	Benchmark	Site on Owen Creek. This site receives run-off predominantly from forested areas with little to no clearing. There is some track development and a minor residential component within the catchment for this site. Given the low level of development upstream, this site was selected as a benchmark$^{\$}$ site for the project area.
SW09	Benchmark	Site on Haren Creek, approximately 2.0 kilometres upstream of site SW02 and adjacent to the project area's southern boundary. This site receives run-off from upstream forested areas, tourist operations, the Kennedy Highway and residential areas. This is a background$^{\$}$ site for the project area.
SW02	Monitoring impacts within property	Site on Haren Creek, approximately 3 kilometres upstream of the confluence of Owen Creek and Haren Creek. This site is downstream of SW09 and the proposed Rainforest Education Centre and upstream of most other proposed KUR-World infrastructure.
SW02B	Monitoring impacts within property	Site on Haren Creek approximately 100 metres upstream of the confluence of Owen Creek and Haren Creek. The site is downstream of components of the project area including the proposed Golf Course, Premium Villas and Lifestyle Villas. The site is approximately 550 metres downstream of the Haren Creek Weir.
SW03	Monitoring impacts within property	Site on Owen Creek approximately 100 metres downstream of the confluence of Owen Creek and Haren Creek. The site is downstream of sections of the Golf Course, accommodation areas, the Produce Garden and sections of the Farm Theme Park and Equestrian Centre.
SW04	Monitoring water leaving site	Site on an unnamed drainage line discharging into Owen Creek, approximately 330 metres downstream of the farm dam. This site is on the downstream project area boundary.

Site	Purpose	Justification
SW06	Monitoring water leaving site	Site on Cain Creek, 300 metres west of the existing farm homestead. This site is on the downstream project area boundary and receives run-off from the project area, including the proposed Golf Course, Premium Villas, KUR-Village, Farm Theme Park and Equestrian Centre and Services and Infrastructure Area.
SW08	Monitoring water leaving site	Site on unnamed tributary of Warril Creek. This site is on the downstream project area boundary and receives run-off from the project area, including the proposed Golf Course, Golf Clubhouse and Function Centre and Five Star Eco Resort.

$ The term "benchmark" has been used to describe site SW01, which is upstream of the project area but may be influenced by some track development within the property upstream of the site. The term "background" has been used to describe site SW09, which is upstream of the project area and influenced by off-site activities (for example tourist operations, residential areas). For the purposes of impact assessment, these sites provide benchmark conditions for comparison to water quality in sites adjacent to and downstream of the project area.



Note: Sites nominated during pre-development surveys can be moved or replaced as required to ensure potential impacts from the development area are appropriately monitored.

Figure 9-5 Recommended surface water and groundwater quality monitoring sites.

9.8.1.3 Timing

The EHP draft 2017 *Monitoring and Sampling Manual* (EHP & DSITI 2017) refers to ANZECC and ARMCANZ (2000) for determining the appropriate frequency of surface water sampling. Although no specific guidance is provided, it is recommended that the frequency is established to meet the programme's objectives.

ANZECC and ARMCANZ (2000) recommend that guideline values are calculated from monthly observations. The Queensland Water Quality Guidelines (QWQG) (EHP 2013b) also adopt this approach. Therefore, surface water samples should be collected from benchmark[5] and receiving sites on a monthly basis. The requirements for ongoing monitoring following completion of the proposed development should be reviewed with consideration to the management of potential ongoing impacts and all development approvals conditions (including EAs issued for ERAs).

9.8.1.4 Methods

Monitoring should be undertaken in accordance with the methods outlined in the EHP *Monitoring and Sampling Manual* (EHP 2013a) (or most recent version).

In place measurement should be made for water quality indicators that can change rapidly after sampling, and for which reliable field measurements can be recorded (for example pH, EC, turbidity, dissolved oxygen, temperature). Measurements should be made using calibrated water quality meters with resolution sufficient to determine water quality against the WQOs. Samples for laboratory analysis should be collected using suitable containers, following appropriate sample preservation methods and be received by the laboratory within the holding times for each analyte.

9.8.1.5 Laboratory analysis

Surface water samples should be analysed by a NATA accredited laboratory. The laboratory LOR required to assess the surface water quality at monitoring sites against the WQOs should be achieved for each analyte to allow appropriate impact assessment during data analysis.

Quality assurance samples should be analysed for the same analytes as the monitoring site samples.

9.8.1.6 Quality assurance

Quality assurance measures that should be employed during surface water sampling include:

- calibration of water quality meters
- decontamination of sampling equipment between sites
- collection of field blank and field duplicate samples
- field-filtration where required using disposable filtering equipment with 0.45 micrometre filters to prevent cross-contamination and preserve sample integrity
- chain of custody documentation for all samples submitted to the laboratory
- use of a NATA accredited laboratory
- review of laboratory certificates for potentially erroneous results or gross contamination
- data management to ensure information can be easily retrieved in the future.

[5] The QWQG (EHP 2013b) recognise that the application of site-specific guideline values derived from reference (relatively undisturbed) condition systems may create unreasonable WQOs for waters in urban environments and that the reference condition concept can be modified for application to more disturbed systems. The QWQG advise that in an urban situation it might be useful, for example, to use the least disturbed urban creek sites to derive reference values and guidelines to be applied to other urban creeks to provide more realistic expectations for desired water quality. Given the upstream impacts identified for the KUR-World project area, the nominated sites for the calculation of site-specific guideline values (SSGVs) are referred to as "benchmark" sites.

9.8.1.7 Data analysis

Surface water quality data should be compared to the WQOs. This analysis will provide an indication of potential impacts on the EVs.

In the early stages of implementing the monitoring programme, reliance will primarily be on existing published default WQOs (Table 9-2). Once sufficient benchmark data has been collected, site-specific guideline values (SSGVs) can be derived for the aquatic ecosystem EV[6]. The SSGVs recognise the quality of water entering the project site may not meet default WQOs, and SSGVs provide a more useful benchmark for assessing potential impacts or improvements. They are designed as a management tool to assist in managing water quality. The SSGVs are not static and will continue to change as more benchmark data is collected. Updated SSGVs should be calculated as water quality monitoring results are received. Monitoring results from the receiving environment can then be compared to SSGVs to identify whether potential impacts or improvements have occurred.

The collection and assessment of baseline (pre-development) water quality monitoring data from sites upstream, within and downstream of the project provide the most appropriate data for setting benchmark conditions, and provide a better indication of potential future impacts and improvements than upstream and downstream data comparisons made following the commencement of development. This is particularly relevant for the KUR-World project area where water quality within the project area under pre-development conditions was of poorer quality for a number of analytes than at benchmark sites. Baseline monitoring data should continue to be collected during the pre-development period.

9.8.1.8 Reporting and review

A database of surface water quality results should be maintained to assist in the comparison and interpretation of results. Surface water quality results should be compared to WQOs and upstream conditions to identify where changes to water quality indicate that the management intent has not been met or where impacts to the receiving environment have potentially occurred.

9.8.1.9 Response to adverse results

Where surface water quality results indicate that the management intent has not been met, or where impacts to the receiving environment have potentially occurred, an investigation into the source of contamination should occur and mitigation measures should be implemented.
Mitigation measures may include:

- additional controls to prevent the continued release of contaminants (for example additional ESC controls)
- clean-up requirements (for example removal of sediment deposition from creek bed)
- impact investigation monitoring (for example aquatic ecosystem (aquatic macroinvertebrate) survey).

The appropriate mitigation measures should be determined on a case-by-case basis.
Department of Environment and Science (DES) must be notified if it is evident that environmental harm has been caused or there is a potential for environmental harm to be caused.

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[6] The QWQG (EHP 2013b) and ANZECC and ARMCANZ (2000) provide guidance on how SSGVs for the protection of slightly-to-moderately disturbed aquatic ecosystems should be derived. The SSGV should be calculated as the 80th percentile (and 20th percentile for pH and dissolved oxygen) of benchmark site data. A minimum of 8 sample values per benchmark site is required to develop interim SSGVs. The interim SSGVs can be updated and replaced once 18 sample values for each benchmark site have been obtained (18 sample values are required where there are one or two benchmark sites only).

9.8.1.10 Mitigation strategies and contingency

In addition to the recommended routine monthly programme, monitoring should be initiated in the event of unplanned discharge of contaminants and sediments from ESC structures, WSUD and stormwater controls to the receiving environment during construction and operation stages.

During this contingency monitoring, it may be necessary to amend the sites or indicators monitored to ensure the potential impacts resulting from the event triggering the monitoring can be assessed and managed as required. Professional advice should be sought.

9.8.2 Groundwater

Groundwater monitoring should be undertaken to identify potential impacts to water level and quality arising from site activities.

9.8.2.1 Analytical suite

The analyte suite used during the baseline groundwater quality monitoring programme can be used as the basis for future monitoring, with the addition of hydrocarbons (associated with vehicle use on bitumen roads) and microbial indicators (related to the operation of the WWTP). In addition, the water level should be recorded. Key risks identified for groundwater quality are related to infiltration of stormwater from roads, roof tops and hard stand areas and nutrient inputs from sewerage and the application of fertilisers to landscaped areas.

Where the use of pesticides is introduced to the Golf Course or landscaped gardens, the analyte list should be updated to include the specific pesticides known to be in use.

A number of analytes were not detected (that is were recorded below laboratory LOR) during baseline groundwater monitoring. Some analytes could be removed from future monitoring programmes if it can be demonstrated that they are not impacted by site activities.

9.8.2.2 Sites monitored

Project area groundwater monitoring sites (WB2, WB5, WB6, WB7, WB8) should be included in the routine monitoring programme (Table 9-8, Figure 9-5), as well as any future groundwater bores installed in the project area. It is recommended that a monitoring bore providing benchmark conditions for the site be included in the monitoring programme.

Table 9-8 Justification for inclusion of groundwater quality monitoring sites.

Site	Purpose	Justification
WB2	Monitoring impacts within property	WB2 is in the northern section of the project area, south of WB05 and adjacent to the Produce Garden and Farm Theme Park and Equestrian Centre. It is understood that WB2 and WB3 are connected in tandem to a common pipeline (RLA 2017) and WB2/WB3 may be used as a water source for KUR-World.
WB5	Monitoring impacts within property	WB5 is in the northern section of the project area, adjacent to the Farm Dam and Farm Theme Park and Equestrian Centre. WB5 recorded a low pumping rate (RLA 2017), but may be used as a water source for KUR-World.
WB6	Monitoring impacts	WB6 is in the north-western section of the project area, east of WB7 and down gradient of most of the project area, including the proposed Lifestyle Villas, Premium Villas and Golf Course. WB6 may be used as a water source for KUR-World.

Site	Purpose	Justification
	within property	
WB7	Monitoring impacts within property	WB7 is in the north-western section of the project area, down gradient of most of the project area, including the proposed Lifestyle Villas, Premium Villas and Golf Course. WB7 may be used as a water source for KUR-World.
WB8	Monitoring impacts within property	WB8 is in the northern section of the project area, adjacent to the proposed KUR-Village and Business and Leisure Hotel and Function Centre and down gradient of sections of the Golf Course, Golf Clubhouse and Function Centre, Sporting Precinct, and Services and Infrastructure area.

9.8.2.3 Timing

Groundwater monitoring should be undertaken quarterly.

The requirements for ongoing monitoring following completion of the proposed development should be reviewed with consideration to potential ongoing impacts and development approval conditions (including EAs issued for ERAS).

9.8.2.4 Methods

Monitoring should be undertaken in accordance with the methods outlined in the DES *Monitoring and Sampling Manual* (EHP 2013a) or most recent version.

In place measurement should be made for water quality indicators that can change rapidly after sampling, and for which reliable field measurements can be recorded (for example pH, EC, temperature). Measurements should be made using calibrated water quality meters with resolution sufficient to determine water quality against the WQOs. Samples for laboratory analysis should be collected using suitable containers, follow appropriate sample preservation methods and be received by the laboratory within the holding times for each analyte.

9.8.2.5 Laboratory analysis

Groundwater samples should be analysed by a NATA accredited laboratory. The laboratory LOR required to assess the water quality at monitoring sites against the WQOs should be achieved for each analyte to allow appropriate impact assessment during data analysis.

Quality assurance samples should be analysed for the same analytes at the monitoring site samples.

9.8.2.6 Quality assurance

Quality assurance measures that should be employed during groundwater sampling include:

- calibration of water quality meters
- decontamination of sampling equipment between sites
- collection of field blank and field duplicate samples
- field-filtration where required using disposable filtering equipment with 0.45 micrometre filters to prevent cross-contamination and preserve sample integrity
- chain of custody documentation for all samples submitted to the laboratory
- use of a NATA accredited laboratory
- review of laboratory certificates for potentially erroneous results or gross contamination

- data management to ensure information can be easily retrieved in the future.

9.8.2.7 Data analysis

Groundwater quality data should be compared to the WQOs. This analysis will provide an indication of potential impacts on the EVs.
In the early stages of implementing the monitoring programme, reliance will primarily be on existing published default WQOs (Table 9-5). Where an appropriate benchmark groundwater bore is identified/installed and sufficient benchmark data has been collected, SSGVs can be derived for the aquatic ecosystem EV[7]. The SSGVs recognise the quality of groundwater in the project site may not meet default WQOs, and SSGVs provide a more useful benchmark for assessing potential impacts or improvements. They are designed as a management tool to assist in managing water quality. The SSGVs are not static and will continue to change as more benchmark data is collected. Updated SSGVs should be calculated as water quality monitoring results are received. Monitoring results from the groundwater receiving environment can then be compared to SSGVs to identify whether potential impacts or improvements have occurred.

The collection and assessment of baseline (pre-development) water quality monitoring data from groundwater sites relevant to the project area provide the most appropriate data for setting benchmark conditions and provide a better indication of potential future impacts and improvements than up gradient and down gradient data comparisons made following the commencement of development. Baseline monitoring data should continue to be collected during the pre-development period.

9.8.2.8 Reporting and review

A database of groundwater quality results should be maintained to assist in the comparison and interpretation of results. Groundwater quality results should be compared to WQOs to identify where changes to water quality indicate that the management intent has not been met or where impacts to the groundwater receiving environment have potentially occurred.

9.8.2.9 Response to adverse results

Where groundwater quality results indicate that the management intent has not been met or where impacts to the receiving environment have potentially occurred, an investigation into the source of contamination should occur and mitigation measures should be implemented.
Mitigation measures may include:

- additional controls to prevent the continued release of contaminants (for example adjustment to effluent irrigation regime, reduction in abstraction volumes)
- clean-up requirements (for example pumping out contaminated bore)
- impact investigation monitoring (for example additional monitoring of local groundwaters to identify scale of impact).

The appropriate mitigation measures should be determined on a case-by-case basis.
DES must be notified if it is evident that environmental harm has been caused or there is a potential for environmental harm to be caused.

[7] The QWQG (EHP 2013b) and ANZECC and ARMCANZ (2000) provide guidance on how site-specific guideline values (SSGVs) for the protection of slightly-to-moderately disturbed aquatic ecosystems should be derived. The SSGV should be calculated as the 80th percentile (and 20th percentile for pH and dissolved oxygen) of benchmark site data. A minimum of 8 sample values per benchmark site is required to develop interim SSGVs. The interim SSGVs can be updated and replaced once 18 sample values for each benchmark site have been obtained (18 sample values are required where there are one or two benchmark sites only).

9.8.3 Aquatic ecology

Aquatic ecology surveys (aquatic macroinvertebrates) should be undertaken twice annually, along with sediment monitoring and in conjunction with a monthly surface water quality survey to assess potential impacts from the proposed development on aquatic ecosystems of the receiving environment.

9.8.3.1 Indicators monitored

It is recommended that the indicators monitored during the baseline aquatic ecology monitoring programme are used for future monitoring (that is aquatic macroinvertebrates, surface water, stream sediment). These indicators were selected to provide information on characteristics of the aquatic ecosystem likely to be influenced by the development.

Project area surface water sites upstream and downstream of discharge areas (for example SW01, SW09, SW03, SW06 and SW08) should be included in the monitoring programme, as well as additional sites where the specific location of discharge infrastructure is known (for example downstream of the WWTP, downstream of confluence of the farm dam receiving catchment and Owen Creek, downstream of stormwater discharge points). Site SW04 was not considered appropriate for aquatic macroinvertebrate monitoring as water is not retained at the site for sufficient time periods to allow the establishment of a macroinvertebrate community. Where possible, a site downstream of the SW04 tributary and Owen Creek should be selected for inclusion in the aquatic ecology (aquatic macroinvertebrate) monitoring programme.

Monitoring sites may change between construction and operational phases depending on the source of potential discharge and impact. Monitoring sites included in the routine programme should be reviewed prior to commencement of each stage of project development and on completion of the construction phase.

9.8.3.2 Timing

The AUSRIVAS sampling methods for Queensland (DNRM 2001) recommend biannual sampling, conducted early in the wet season (after the waterway has been flowing for a minimum of 4 weeks), and at the end of the wet season during the recessional flow period (at least 4 weeks after the last flushing event).

The timing of the aquatic macroinvertebrate aspect of the field survey is dependent on flows in the watercourse, particularly the occurrence of high flows that ‘flush’ the system. To allow the aquatic macroinvertebrate community to re-establish at the monitoring sites, it is important that at least four weeks of base flow occur after a high flow/flushing event. Publically available stream flow monitoring data should be used when planning the timing of each aquatic ecosystem survey.

A minimum of two aquatic ecosystem (aquatic macroinvertebrate) surveys (including sediment monitoring) are recommended per year, timed to occur at a minimum of 4 weeks, but preferably 6 – 8 weeks, following flushing of the creeks.

The requirements for ongoing monitoring following completion of the proposed development should be reviewed with consideration to potential ongoing impacts and development approval conditions (including Environmental Authorities issued for ERAS).

9.8.3.3 Methods

9.8.3.3.1 Aquatic Macroinvertebrates

Aquatic macroinvertebrate samples should be collected using a 250 micrometre dip net following the bed habitat. This involves the operator using their feet to disturb the substrate while sweeping the net downstream of the plume to capture dislodged organisms, while moving upstream along a 10 metre transect. Net contents are then emptied into white sorting trays and all organisms[8] encountered over a 30 minute period are field-picked into ethanol. Preserved samples are taken for laboratory identification.

A minimum of three replicate samples should be taken at each site during the construction phase to provide an understanding of the natural variability in the aquatic macroinvertebrate community. Differences in micro-habitat between replicates and between sites should be noted on field proformas to inform data interpretation if needed. Where possible, similar micro-habitats between control and receiving sites should be sampled.

9.8.3.3.2 Sediment

Sediment sample collection should target depositional zones in the watercourse because the purpose of the study is to determine if contaminants released from the monitored activity are accumulating in the receiving environment. Composite samples should be collected from 10 subsampling points within depositional zones at each site. A stainless-steel trowel should be used for sampling. Sample depth should be standardised, where possible, to ensure only the surface sediment (most recently deposited) is collected (no more than 5 centimetres deep). Each of the 10 subsamples should be combined in a bucket and mixed well to homogenise the sample. Rocks bigger than 25 millimetres in diameter should be removed. The entire sample should be placed in an appropriate sample container provided by the laboratory[9] and provided to the laboratory for sieving and riffle-splitting.

A duplicate sample should be prepared in the field and analysed by the laboratory for quality assurance purposes. This sample should be split in the field using a method that reduces variability between the samples, particularly with grain size (for example 'coning' and 'quartering').

It is recommended that the analytes monitored in sediment samples collected during the baseline aquatic ecology (aquatic macroinvertebrate) survey are used for future monitoring, with the addition of hydrocarbons (associated with vehicle use on bitumen roads).

Where the use of pesticides is introduced to the Golf Course or landscaped gardens, or for termite control, then the sediment analyte list should be updated to include the specific pesticides known to be in use.

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[8] AUSRIVAS field sampling requires up to 10 specimens from each taxon be picked in each sample. This approach is based on a rapid assessment where the data is analysed using presence/absence metrics. This method provides poor resolution for determining local scale impacts, and limits the ability for the data to be used in more meaningful multivariate statistics and other indices. An alternative field-picking approach, where as many individuals of each specimen as possible are collected, is recommended. This approach has been implemented at metalliferous mine sites for EA monitoring since the early 2000s. The method has been accepted by EHP for routine and investigation monitoring, and has been reliably used for determining potential impacts to, and recovery of, aquatic macroinvertebrate communities due to poor quality water released from numerous operations in north Queensland (personal observation of Shannon Wetherall, Senior Environmental Scientist, NRA). The benefits of this modified AUSRIVAS approach is that more detailed statistical analysis can be undertaken, while preserving the ability for AUSRIVAS models and other indices to be used if required.

[9] Where hydrocarbons are included in the monitoring suite, collection of samples into glass jars may be required. Contact the laboratory for advice on appropriate sample containers and sample volumes.

9.8.3.3.3 Laboratory analysis

Sediment samples should be analysed by a NATA accredited laboratory. The laboratory LOR required to assess the stream sediment quality at monitoring sites against published guideline values should be achieved for each analyte to allow appropriate impact assessment during data analysis.

Particle size distribution (PSD) should be completed on the same composite sample as that analysed for chemical properties. The PSD should use a defined set of sieve sizes, with the minimum being <63 micrometres.

Quality assurance samples should be analysed for the same analytes as the monitoring site samples.

9.8.3.3.4 Quality assurance

Quality assurance measures that should be employed during aquatic ecology (aquatic macroinvertebrate) surveys include the following.

- Identification and counts of a sub-set of aquatic macroinvertebrate samples by a second experienced scientist to confirm identifications.
- Collection of residual samples to verify the live-picking capability of each operator.

Quality assurance measures that should be employed during sediment sampling include:

- decontamination of sampling equipment between sites
- collection of field duplicate samples
- chain of custody documentation for all samples submitted to the laboratory
- use of a NATA accredited laboratory
- review of laboratory certificates for potentially erroneous results or gross contamination
- data management to ensure information can be easily retrieved in the future.

9.8.3.3.5 Data analysis

Sediment quality data for the whole sediment (<2 millimetre fraction) should be compared to published guideline values (Simpson and others 2013) to provide an indication of the condition of stream sediments in the receiving environment.

In the early stages of implementing the monitoring programme, reliance will primarily be on existing published guideline values (Simpson and others 2013). Once sufficient benchmark data has been collected, SSGVs can be derived for the aquatic ecosystem EV[10]. The SSGVs recognise the quality of sediment in the project site may not meet published guideline values, and SSGVs provide a more useful benchmark for assessing potential impacts or improvements. They are designed as a management tool to assist in managing sediment quality. The SSGVs are not static and will continue to change as more benchmark data is collected. Updated SSGVs should be calculated as sediment quality monitoring results are received. Monitoring results from the receiving environment can then be compared to SSGVs to identify whether potential impacts or improvements have occurred.

A range of statistical analyses will be used to investigate spatial and temporal relationships between aquatic macroinvertebrate assemblages at the monitoring sites. The analysis will include the following.

[10] Simpson and others (2013) suggest a SSGV for sediment in moderately disturbed systems be derived on the basis of the median of benchmark concentrations multiplied by a factor of two.

- Univariate analysis, such as histogram graphs to display taxa abundance and richness results.
- Multivariate analysis, such as cluster analysis and multidimensional scaling (MDS). This analysis is undertaken using statistical software (for example PRIMER). To assist in interpretation, cluster analysis results may be overlain onto the MDS plots, and the significance of clusters can be assessed using a SIMPROF test (Clarke & Gorley 2006). Further interrogative analysis may be undertaken, for example SIMPER and BIOENV.
- Other common indices include:
  - PET richness[11]
  - SIGNAL2 index[12]
  - taxa richness[13]
  - % sensitive taxa[14]
  - % tolerant taxa[15].

The analyses should be undertaken by personnel with relevant experience in preparing and interpreting these statistical outputs.

9.8.3.4 Reporting and review

A database of aquatic macroinvertebrate abundance and sediment quality should be maintained to assist in the comparison and interpretation of results. Sediment results should be compared to published guideline values, and sediment and aquatic macroinvertebrate results should be compared across sites and surveys to identify where changes to aquatic macroinvertebrate communities and sediment quality indicate that the management intent has not been met or where impacts to the receiving environment have potentially occurred.

9.8.3.5 Response to adverse results

Where aquatic macroinvertebrate and/or sediment quality results indicate that the management intent has not been met, or where impacts to the receiving environment have potentially occurred, an investigation into the source of contamination should occur and mitigation measures should be implemented.

Mitigation measures may include:

- additional controls to prevent the continued release of contaminants (for example additional ESC controls)
- clean-up requirements (for example removal of sediment deposition from creek bed)
- impact investigation monitoring (for example expansion of aquatic ecosystem (aquatic macroinvertebrate) monitoring programme with additional surveys or monitoring sites).

The appropriate mitigation measures should be determined on a case-by-case basis.

DES must be notified if it is evident that environmental harm has been caused or there is a potential for environmental harm to be caused.

9.8.3.6 Mitigation strategies and contingency

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[11] PET richness is the total number of families in the orders Plecoptera, Ephemeroptera and Trichoptera present in a sample. Macroinvertebrates in these orders are considered to be sensitive to human disturbance (EHP 2013a).

[12] SIGNAL2 (stream invertebrate grade number average level) index allocates a sensitivity grade number to macroinvertebrate families based on their sensitivity to various water quality changes.

[13] Taxa richness is the total number of different aquatic macroinvertebrate families in a sample.

[14] % sensitive taxa is based on the proportion of taxa with 'sensitive' SIGNAL2 grades of 8-10.

[15] % tolerant taxa is based on the proportion of taxa with 'tolerant' SIGNAL2 grades of 1-3.

In addition to the recommended routine monthly programme, aquatic ecosystem monitoring should be initiated in the event of accidental discharge of contaminants and sediments during construction.

During this contingency monitoring, it may be necessary to amend the sites or indicators monitored to ensure the potential impacts resulting from the event triggering the monitoring can be assessed.

9.9 Conclusion

The site is located approximately 2 kilometres from the Wet Tropics of Queensland World Heritage Area and the Wet Tropics of Queensland National Heritage Place, and approximately 8.5 kilometres from the Great Barrier Reef World Heritage Area and the Great Barrier Reef National Heritage Place. The project area is located in the Barron River catchment, with three local sub-catchments recognised within the project area (Owen Creek, Warril Creek and Cain Creek). All creeks discharge to the Barron River approximately 1 kilometre north of the project area. The Barron River ultimately discharges to the Great Barrier Reef Marine Park, approximately 25 kilometres downstream of the site.

There is commonality of purpose and approach to the management of water quality across the jurisdictional boundaries associated with World Heritage Areas and the like that are relevant to the project. Sites waters are mapped as moderately disturbed (MD). The most important existing impacts on surface water quality are accelerated soil erosion and an increased load of total suspended solids and associated turbidity, metals and nutrients. MD WQOs are not being achieved under baseline conditions in the waters of the project area, and the receiving environment has no further assimilative capacity for some water quality indicators. This has important implications for the proposed management of discharges to receiving waters and has been considered in the planning of the project and the development of mitigation measures.

The management intent for MD waters is that the decision to release waste water or contaminants into a waterway must ensure the measures of physical or chemical indicators are progressively improved to achieve the nominated WQOs. Achieving a WQO means that the corresponding EV (and associated use) will be protected. Therefore, management of point and diffuse sources from the KUR-World development should ensure that receiving water quality progressively improves and that the project design and operation should aim to have a net positive impact on water quality. In terms of water quality, the discussion and conclusion presented in Chapter 8 (Flora and Fauna) in regard to significant residual impact is relevant; hence the importance of management measures specific to erosion and sediment control and site water management.

The potential impacts to surface water and groundwater from the KUR-World development include spills of hazardous chemicals, land clearing, stormwater and waste water; these are expected to be mitigated through appropriate on-site management of hazards, with spills contained and cleaned up. Potential impacts to the receiving environment will be mitigated by the capture and treatment of site waters through stormwater management Water Sensitivity Urban Design (WSUD) and a waste water treatment system. An Erosion and Sediment Control Plan (ESCP) will be developed for construction and operation to minimise erosion and sediment loss. Nutrient loads from the Waste Water Treatment Plant (WWTP) discharge will be offset by improving water quality through mitigation measures in the catchment that receives discharge, and rehabilitation plans for improving frog habitat are expected to have a positive impact on water quality. Where on-site treatment alone is unlikely to allow direct discharge and achievement of the management intent as defined in the EPP (Water), additional mitigation measures have been proposed.

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